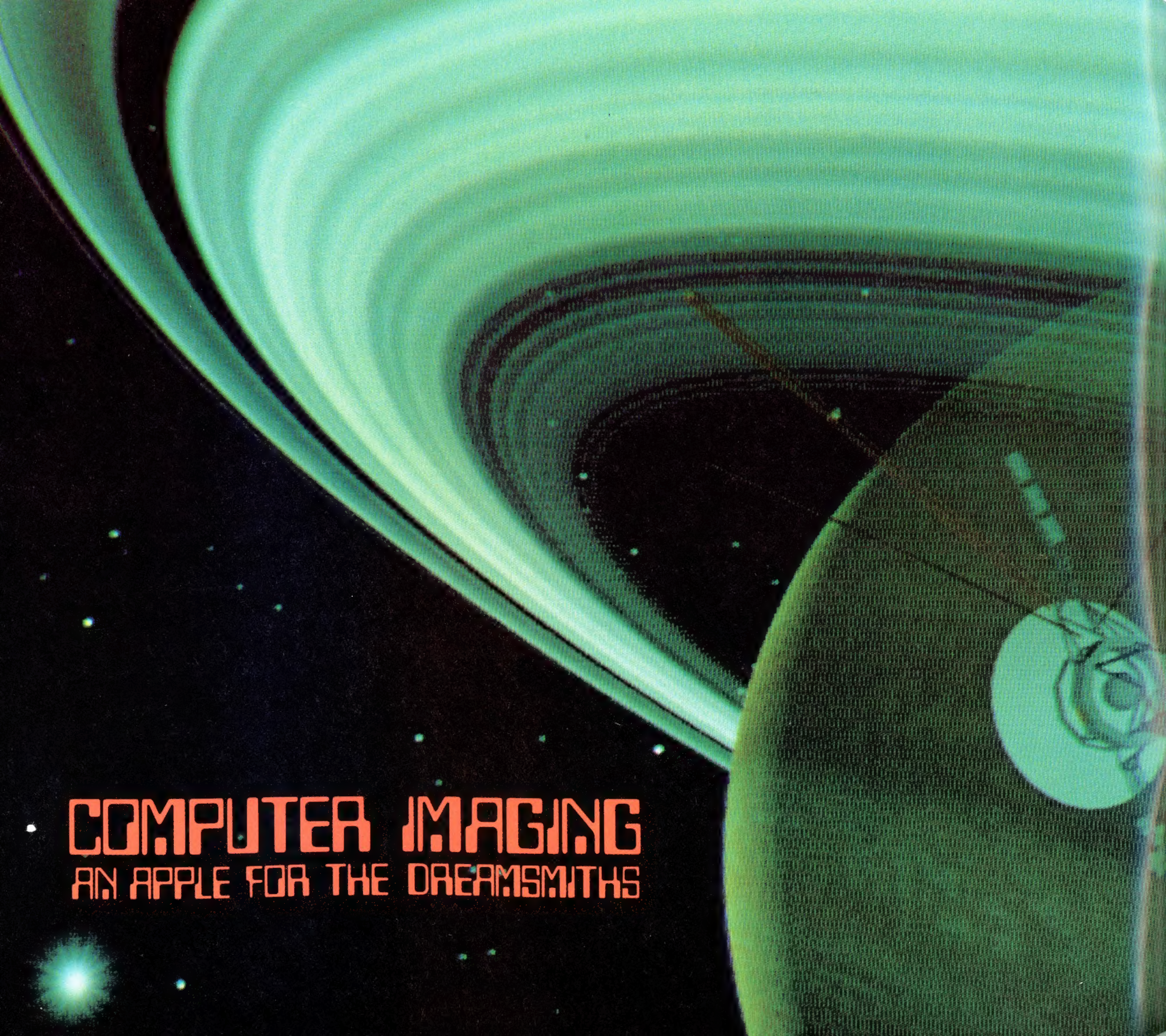


COMPUTER IMAGING

AN APPLE FOR THE DREAMSMITHS

Imagine yourself the director of a big-budget science fiction film, working on a special effects sequence involving the rescue of some endangered earthlings by a friendly alien spaceship. For this particular scene, however, instead of using models and motion control photography, imagine yourself employing the hottest new motion picture technology of the mid-1980s — computer-generated object simulation and electronic compositing.

You are working in a room full of electronic equipment, facing a wall of video monitors. You lean back in a chair with your coffee (or Heineken, if you prefer) while the technical director shows you the designs for some spaceships you worked on earlier. He punches a few buttons, and several screens light up showing different kinds of interplanetary vehicles, rendered in full perspective with absolutely convincing shadows and highlights. The ships look photographically real, and careful examination of any part of them reveals a wealth of subtle detailing. They have, in fact, been lovingly modeled — but not from cannibalized plastic kits, or any other material substance. Instead, they are like spirits in the machine — they are software spaceships.

You begin the session by loading the main computers: "All right, Bob, take the one on screen five — the one the producer liked — and dump it into the main box. And take the dolphin-like alien ship that's on seven; we'll use that for the rescue craft." Bob loads the main computer with the data on the two ships from a disc storage unit that makes a few brief purring sounds. The chosen vessels now appear on the main viewing screen.

"Give us the environment with the neutron star we made yesterday, and program the star's gravity to be twice as powerful as it was. I want things to move a lot faster this time." Bob pokes at the keyboard again and suddenly the background is filled with billowing wisps of the Milky Way. A small silver orb shimmers in the center as if it were a vibrating droplet of mercury. Immediately the two spaceships start to fall slowly towards the neutron star. "Now the fun begins! Bob, you take the earthship. I'll fly the dolphin."

You flip a switch and a console that looks rather like the controls of a Piper Cub lights up in front of you. You glance at the storyboards one last time to memorize the scene and then pull back on the joystick and give her some gas. The sleek dolphin-ship loops over and charges up, filling the screen for an instant. Then it's gone, leaving the earthship alone, relentlessly drawn towards the deadly star. Now you refer to a small screen on your instrument panel which shows your own ship's point-of-view, rather than the "camera's." You maneuver around until you can see the star and the other craft on this flight-screen, and then slow your ship to a crawl.

"Okay, Bob, the camera is to follow the earthship at a slightly slower speed so she'll appear to gradually get smaller while the star is coming closer. We want to make it obvious to the audience that there's no time to lose if those folks are to be saved."

There's more fine tuning and tweaking until finally: "Roll the tape . . . slate . . . and we're off!" A character generator — giving the scene number and other pertinent data — is momentarily keyed over the shot as the tape recorder starts up. Now Bob's earth-clipper starts forward in earnest, a delicate blue-violet feather of flame emanating from its giant engine. You wait a moment and then open throttle once again. Like a motorcycle cop roaring out from behind a billboard, you gun your dolphin-ship at full power and charge into the picture. In moments you are alongside the larger vessel — both ships plunging towards the throbbing neutron star.

On the big editing screen, the two ships are beginning to foreshorten and turn bluish as they approach the speed of light. In a heartbeat all would be lost, but your scout-ship has one last trick up its sleeve — the legendary tractor beam that gives you a grip on the earthship, allowing you to turn them both around with a mighty thrust of your graviton engine. Your engine exhaust, the tractor beam, and other like effects are available for adaptation from an ever-growing software library.

You can stop and do it over again — as many times as you need to get the perfect shot — or the computer can replay a take and let you go in and make adjustments. When you're finally done, you can tell the computer to smooth out any rough transitions. Every step of the way you will be saving the necessary data on disc memory, so that all stages of the animation process are available for recall and thus there is no cause for hesitation about making changes or experimenting. Any setup ever made on the system can be recalled in a moment and used as is, or modified.

Hardware for such a system will be superficially similar in many respects to video technology (with all the freedom, speed and flexibility of that medium) but its final product will be a 35mm or 70mm film image of a quality far superior to conventional opticals. At its heart will lie a powerful "number crunching" digital computer that is actually a cluster of smaller computers with vast solid state and disc memories — a spin-off from the technology the auto and aircraft industries have been using for over a decade to assist in their product design. These so-called "computer aided design" techniques, coupled with the related field of image processing, have contributed to the effort to develop the machines and the programs whose creations are just now beginning their debut in motion pictures.

Today's computer animation is almost up to the level of the cinematic system described. We've really only been stretching our imagination with respect to having so many different abilities all wrapped up in one fast and flexible package. But by mid-decade, electronic cinematography will be emerging on several fronts, with image synthesis and image processing — composited with live-action on video-like systems — being the most prominent. Such systems will not, however, be replacing motion control and existing special effects techniques so much as they will be blazing totally new territory.

There can hardly be anyone in the "modern world" who is not aware that electronics is a booming field, and most people also know that it's all because of the ever-smaller-more-sophisticated-

article by
Peter Sørensen

Dr. James F. Blinn's "Evolution of a Goblet" presents a concise visual history of computer imaging. Early computer graphics involved the generation of calligraphic or vector displays — simple line renderings with all sides visible at once. A major advance was the introduction of hidden line removal which allowed the computer to present an object from a specific point of view, but still in vector form. Then, moving toward more realistic representations, computers began filling in the lines and depicting objects as a series of flat polygonal facets. The next major step toward full image synthesis came with the advent of smooth shading, an averaging process which smoothed out the polygonal surfaces. Today, raster graphic systems are able to inject almost limitless detail into their software images. / A scene from Peter Sørensen's "Scanimate Concerto," performed by Phil Zimmerman at Computer Image Corporation. The visual music was intended as background scenery for modern dance.

yet-cheaper micro-circuit technology. It was the invention of the transistor in 1947 that initiated the birth of the Solid State Age. By 1959, many transistors and other elements could be combined on "one tiny chip," and the race for smaller and more complex integrated circuits was off. Over the years, the minute plastic blocks that contained the circuits grew very little, but under a microscope, their insides began to look like an aerial view of some huge city as eventually entire computers were being etched onto the silicon. Today's microprocessors have a hundred thousand components; by 1990 they should have a million or more. Needless to say, the computer business is thriving.

The video industry has also benefited greatly from the microelectronic revolution. Portable cameras and recorders would be impossible to carry if they had to be built with radio tubes inside. Unfortunately, however, the broadcast industry standardized itself long ago with a picture comprised of 525 horizontal lines, a resolution so poor that film-oriented people were convinced there would simply never be a time when video might compete with 35mm for theatrical use. But there *are* advantages to video. With video, you can record an image and play it right back, without waiting overnight for chemical processing. You can also manipulate colors and other aesthetic parameters, do dissolves and keys in real-time, and make many copies of a show simultaneously from one master — all possible because the picture is encoded into an electronic signal.

In film, to composite an object from one piece of film onto a scene from another requires complex optical techniques. In video, it's a breeze. In fact, it's done live a dozen times every night on the evening news. That big rectangular area behind Dan Rather's head is a chroma-key screen. Blue is used most often, but any color can as easily be used to key on, because it's a simple matter for a video switching device to recognize a color by looking for its electronic signature of shade and hue. Wherever it sees the key color, the switcher inserts another video source.

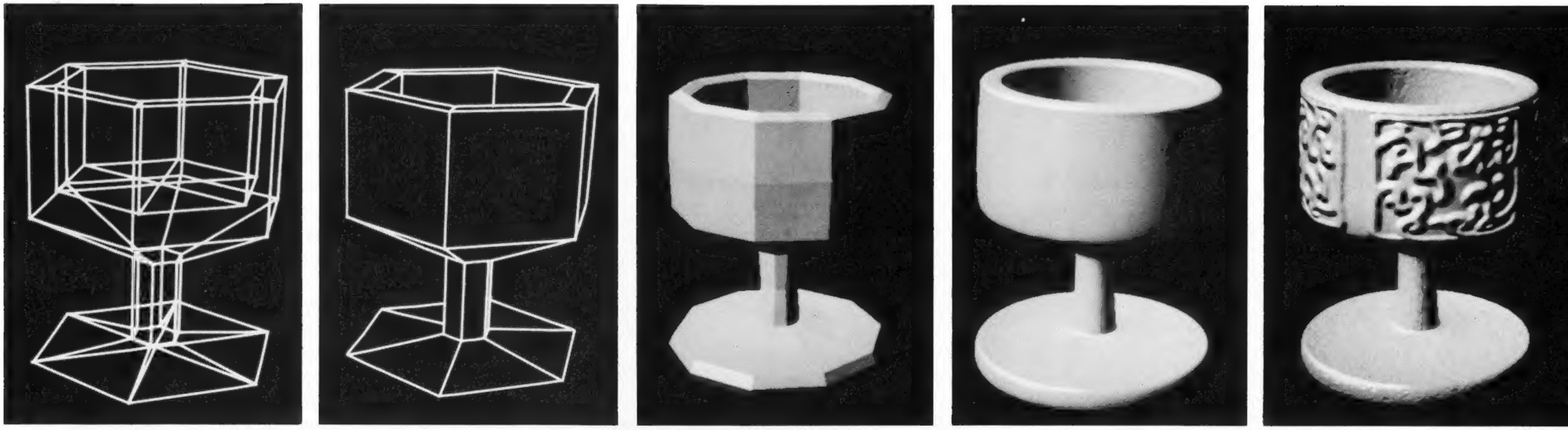
The latest advances in video involve the use of digital techniques which make for zero image deterioration over multiple tape generations, as well as squeeze-zooming and freeze-framing. So, it's not hard to see that if there were satisfactory image resolution, motion picture production — especially editing — could benefit from the broadcast industry's research and development efforts. But what's needed is a TV camera with a resolution greater than 70mm film — and the Japanese are hot on the trail.

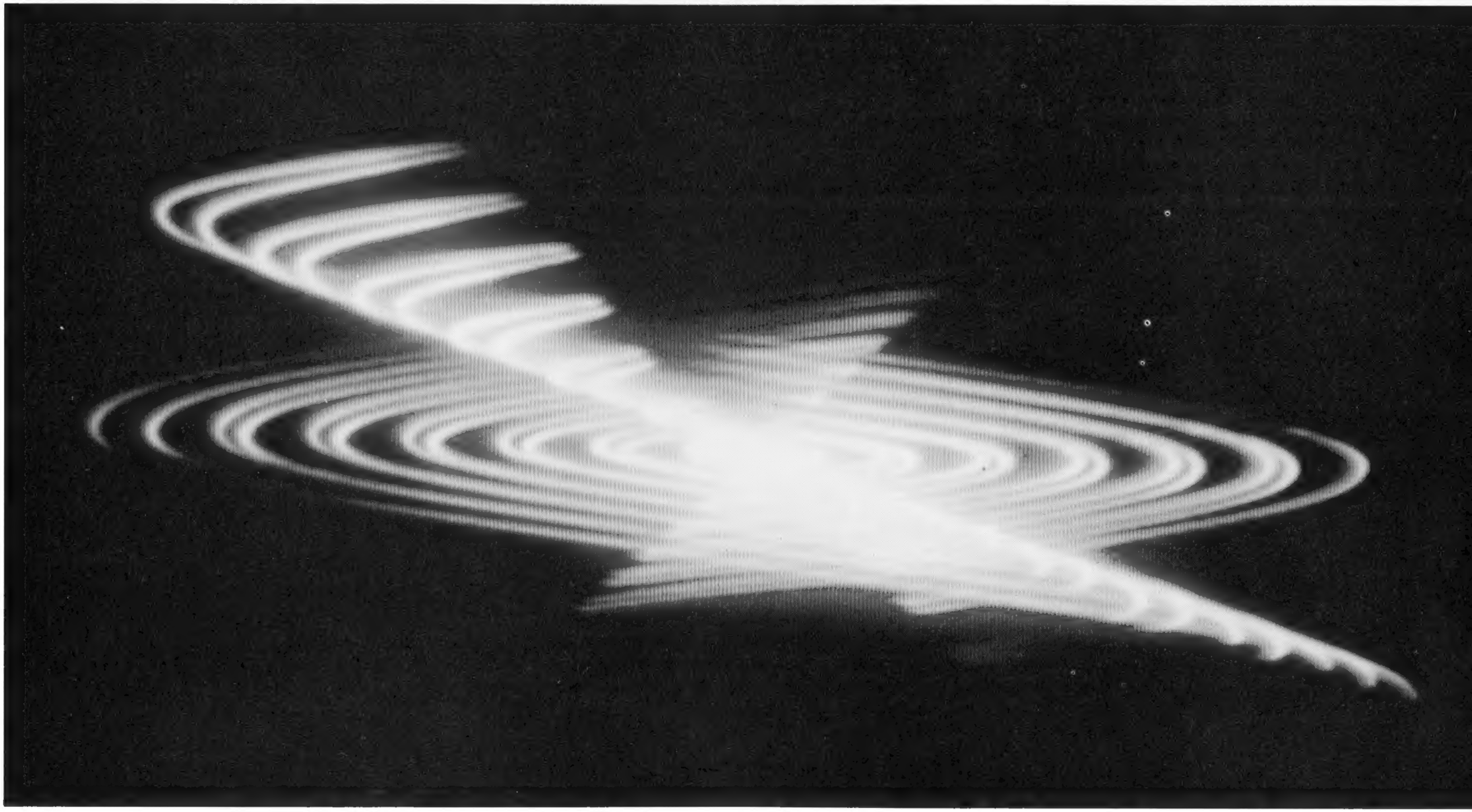
For a long stretch of time, after the fall of Rome, Europe was plunged into the Dark Ages — a period highlighted by non-growth and the preservation of ignorance. But then, as surely as the mammals thrived while the dinosaurs died off, little pockets of learning began to grow; and with the invention of movable type, knowledge became a respectable personal attribute once again. People became interested in how the world around them ticked. It became fashionable to drop feathers and steel balls from tall towers, and to peer through pieces of glass that were cut and bent in curious ways. Isaac Newton discovered that a triangular piece of glass could break white light into a rainbow of color, and that a second such prism could put Humpty Dumpty back together again. The pathway to the present was being blazed. Then, in the late 1800s, a Frenchman named James A. Lissajous stuck little mirrors onto rubber bands, and when he plucked them inside a darkened theater they bounced light around in beautiful patterns. In the 1920s, a Danish-American named Thomas Wilfred took advantage of the powerful new electric theatrical lighting that had become available to construct several large light organs. By means of hundreds of levers and wheels, he was able to control the lights, lenses, mirrors and colored filters in his "Clavilux" projectors, and as a result became very well known for his carefully scored lumokinetic performances.

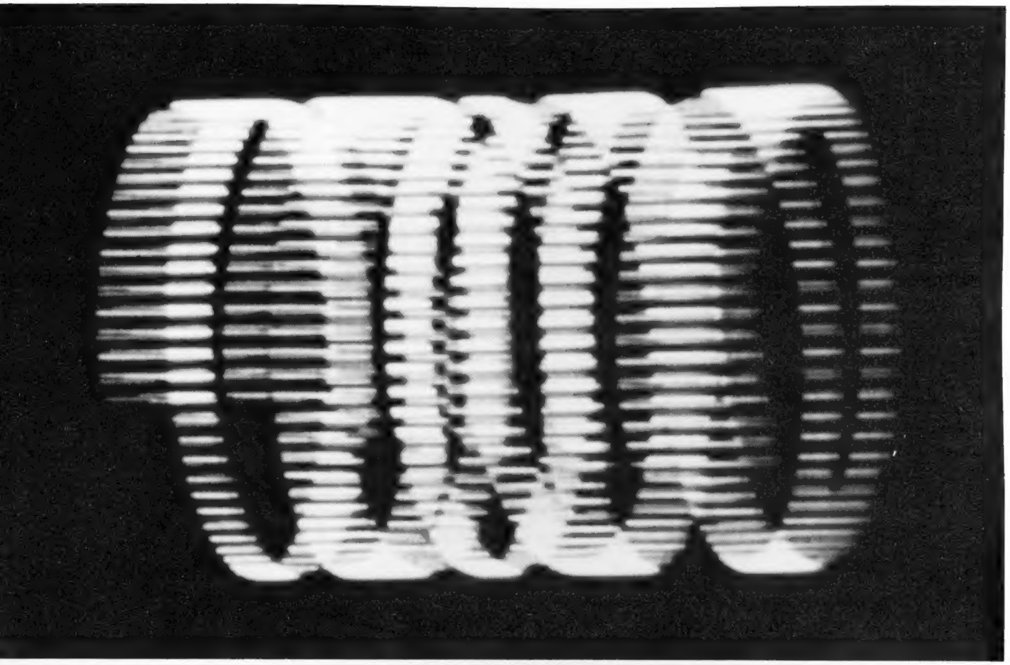
After the first World War, we come to the invention of the cathode ray oscilloscope and the rediscovery of Lissajous patterns — this time made by using electronic oscillators to deflect an electron beam around on the face of a vacuum tube, creating pure sine/cosine wave patterns just like those formed by the vibrating rubber bands seventy-five years earlier. The first electronic computer was built at the end of the second World War and by the 1950s, the world was already beginning to feel the effects of the new technology. A man named Saxenian (his first name is lost to history) coaxed a digital computer into portraying the motion of a bouncing ball — the first computer graphics.

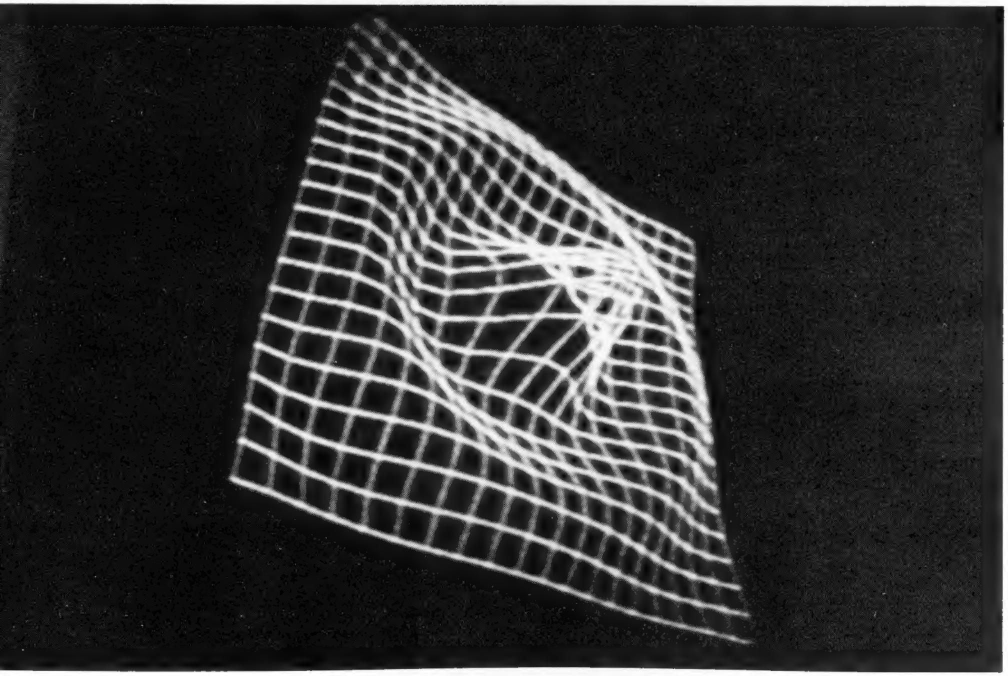
Basically, there are two quite different kinds of computers — analog and digital — with the key difference between them being the difference between waves and pulses of electricity. Digital computers perform calculations in binary math using distinct, individual, on-off pulses of current, while the analog devices perform their functions by manipulating electric waves of variable strength and frequency. A large number on an analog machine would be represented by a relatively high voltage, while a large number on a digital machine would be represented by lots of little electronic ones and zeroes. An abacus is technically a digital computer because either a bead is, or it is not, in a given location — there is no halfway. A slide rule, however, is a basic analog computer because its parts move smoothly in relationship to each other along a graded scale. Infinite variability is possible with analog, but down-to-the-last-decimal-point precision is not. These differences result in totally different areas of specialization for the two systems. Digital computers are used in tasks that require precision — such as keeping accounts — while analog computers are generally put to more intuition-oriented applications. Music synthesizers, for instance, are basic analog computers running at audio frequencies.

In graphics, analog computers are most commonly used for manipulating video pictures off a camera and making Lissajous patterns, while digital computers are best for synthesizing realistic dimensional images. "When you generate something in analog," says veteran analog computer operator Phil Zimmerman, "it's like asking somebody to grow a flower, to construct









curves in the same way as nature does it. But when you do it digitally, it's more like saying, 'I can address each spot, one individual thing at a time.' Whereas nature sort of conceives of things as a whole, the digital viewpoint conceives of things as little individual steps."

Analog computers do not normally have magnetic memory storage like digital computers do. Nor are they programmed in the same way. On an analog machine the operator will construct a meticulously tangled mass of wires as each move is prepared. This "patch" functions somewhat like a telephone switchboard, connecting the many separate parts of the instrument so they all work together.

In 1957, the "father of computer animation," John Whitney Sr., bought an old World War II antiaircraft gun controller — essentially a mechanical analog computer — and put it to the peaceful use of painting with light directly onto movie film by manipulating pinholes and shadow masks. And about that same time, an art and engineering student named Lee Harrison began experimenting with sophisticated ways of making Lissajous patterns using electronic analog computers of his own design.

But the early analog experimenters were regarded by a lot of people as mad scientists. Lee Harrison's neighbors certainly thought he was more than a little peculiar, and surely no more than a handful of engineers understood his video dreams. Though he was ultimately to change the look of television, for several, often hungry, years Harrison recalls warming his house in the winter by the glow of hundreds of electron tubes.

In the Sixties, Harrison made a machine called Animac that could generate puppet-like figures out of high-speed wiggly lines. The puppets could even be animated by attaching an electronic harness to a live dancer. At the heart of the system was a high-resolution cathode ray tube, much like an ordinary TV picture tube. And like an ordinary TV tube, it featured an electron beam which made a spot that varied in strength to give light and dark, while being moved around by a fluctuating magnetic field driven by the computer. In standard video, the beam scans back and forth to fill the screen with regular parallel lines forming what is called the "raster." The Animac, and its descendants, use the same electromagnetic positioning mechanisms for controlling the beam, but freed from the parallel sweep so they can make abstract designs based on the waveforms generated in the computer. Soon Harrison and his friends were creating the snazziest Lissajous patterns in history.

A popular child's toy called "Etch-A-Sketch" comes to mind when discussing video computers, because the toy draws pictures — on a glass screen coated from the inside with silver dust — in much the same manner that its electronic big brother draws on a phosphor-coated screen with an electron beam. To make a picture on the "Etch-A-Sketch," one manipulates a scriber by the use of two knobs: one for left/right and one for up/down — it takes a lot of patience. In the computer, control of the electromagnetic field maneuvers the electron beam to make patterns in the same fashion. A different toy demonstrates yet another analog aspect — a toy that is, in fact, an analog computer itself — the delightful "Spirograph," a collection of little plastic gears and rings all meshed together to guide a pencil point through complex, loop-de-loop designs. By using different-sized gears, the gear ratios can be changed, resulting in a new pattern of spiraling loops. Something very similar happens in a video computer when it is generating its own abstract patterns. Instead of plastic wheels, however, there are changing magnetic fields; and instead of the gear teeth, there are variable oscillators powering the magnets, drawing with the electron beam.

But Harrison wasn't just playing around in those early days. He took his ideas to one wealthy investor after another — even to Walt Disney — but no one had the vision to see the value of his work. Then one day an advertiser said, "Come back and see me when you can make the letter A." Up to that point, everything he and his friends had been doing with the puppet-like Lissajous patterns was fairly free-form. They had not been manipulating whole television pictures yet. The solution was to adapt the system so that it manipulated an entire TV raster image, rather than just a squiggly line as before. Some of the most common moves that could be made with the new picture manipulation were imitations of common camera moves, such and pan, tilt and zoom. The more bizarre involved rolling the picture up into a cylinder or a ball, even turning it inside-out. That was in the late 1960s.

Obvious as it may sound now, the idea seemed pretty radical at the time. After all, the television industry had been spending untold millions to perfect a flawless, rock-steady picture. It must have seemed sinful to set about screwing the signal up! But Harrison and his associates began magnetically manipulating a raster as though it were a piece of electronic rubber and soon they had their letter A (and anything else they wanted) flipping, twisting and wobulating its way out over the airwaves. And so it was the Animac begat Scanimate.

Then Scanimate begat Caesar. Caesar is a machine with most of Scanimate's tricks, but with a small digital computer running herd on all the analog functions. (Such analog/digital teams are known as hybrid computers.) Caesar is capable of lengthy and complex moves which can be used to animate cartoon characters, a job that would be too difficult for Scanimate.

These days, Lee Harrison — with associates Bill Altemus, Dr. Ed Tajchman and others at Computer Image Corporation — are working on the next generation of hybrid video computer, called System IV, which will include the best features of the previous three machines, plus some new tricks which at present they are reluctant to discuss.

On the film front, John Whitney Sr. got started making nonobjective motion pictures during the second World War, using an 8mm camera. Whitney produced these early films by photographing handmade artwork and then rephotographing those films on an optical printer he had built with his brother James. Eventually Whitney came to focus most of the creative process on the optical printer. By his use of war surplus equipment he was able, with mere technological tablescraps, to create such films as *Catalog, Permutations,* and others that established him as the senior pioneer in technological art and motion graphics. (Lee Harrison, too, has built many wonderful machines; but he hardly ever used them himself, and none of his art has had public exposure.) Whitney went on to make several striking films and even some commercials and feature film titles. Then in the mid-Sixties he began working with IBM's digital computers on a research grant, and since then most of his art has been produced on digital computers. He currently teaches at UCLA in Los Angeles.

Also in the Sixties, several people were experimenting with various kinds of video-based analog computers, usually synthesizers. There was the Paik-Abe — an instrument that evolved as an extension of Nam June Paik's experiments using magnetic fields to create artworks out of old color television receivers. And then there was the Rutt-Etra machine, which was larger than the Paik-Abe, but smaller than a Scanimate. More Rutt-Etras have been built than any other kind of synthesizer. Most were bought by universities and individual video artists.

Then, quite apart from the scan-manipulation synthesizers, a new angle was being explored simultaneously, but independently, by two young video engineers in San Francisco, back during the days of Haight-Ashbury. The results were Steven Beck's Direct-Video Synthesizer and Eric Siegel's EVS. These systems did not manipulate the electron beam directly, so they needed no rescanning to produce the standard video signal. Instead, they generated their wild, op-art patterns within the context of the video sweep rate, a process that is something like weaving patterns into the blank video raster. But, like the Animac machine, these devices were also ignored by the business world — they were simply ahead of their time.

Except for the Beck and Siegel synthesizers, all the analog machines have in common the use of a standard television camera to translate their nonstandard images into ordinary video signals. This process is called "scan conversion" — from which the Scanimate gets its name. Scan conversion is necessary because almost everything the computers do involves distortion of the strictly regulated parameters of standard video. So the computer simply does its thing, playing it out on its own nonstandard, high-resolution picture tube, where the image is simultaneously being rescanned by the conventional camera, resulting in a standard broadcast signal. All of these various systems were developed primarily to afford creative people access to that magical electron beam in the picture tube, which had previously been totally off limits.

Analog computers have been used in untold thousands of television commercials and related work. Everyone is familiar with their distinctive electronic look. They have also been used occasionally for special effects in feature films. Science fiction fans will remember most of them: *Logan's Run, Demon Seed, Telephon, Hangar 18* and *Star Wars.*

The problem, however, with using video computers for effects in feature films is that the 525-line television image is con-

A Scanimate "Coke-roll" done at Dolphin Productions. The effect — which entails "wrapping" the video raster into a cylindrical shape that can be animated to unwrap and reveal its original image — is used frequently in television commercials, and is so named because of its initial employment in a Coca-Cola spot. / A video readout used on one of the medical bay monitors in Outland *is an example of a familiar vector graphic image called a Bessel diagram.*

Analog animation in Demon Seed, *directed by Ron Hays and performed on an Image West Scanimate by Richard Froman, was used to portray the emotions of the film's super computer through abstract patterns which at times appeared meditative, angry, or — as in the case of this triangular video slitscan — orgasmic. / For the rebel war room scenes in* Star Wars, *Jay Teitzell, John Wash and Dan O'Bannon produced a computerized representation of the Death Star passing behind the planet Tatooine. The Scanimate used was operated by Roy Weinstock, under the direction of Domenic Iaia.*

siderably lower in resolution than movie film. And even though there are new tape-to-film transfer techniques which use lasers to paint the image onto film in such a way that the lines are imperceptably blended into one another, the low amount of image information present is still troublesome to most film people. Nevertheless, these systems have been used quite effectively on a number of occasions — most notably perhaps in *Demon Seed,* a story, ironically enough, about a computer that decides to revolt against its human creators. To try and give the audience a look into the mad computer's mind, the producers hired visual-music maestro Ron Hays to compose some effects. Hays and Scanimate operator Richard Froman came up with some classic visuals at Image West, especially the one for the computer's "orgasm" which made use of many abstract patterns of great beauty, as well as an analog computer version of slitscan. Earlier forms of slitscan — most noticeably employed in the "trip" sequence from *2001: A Space Odyssey* — created a moving image with dramatic perspective by the use of a moving slit during a time exposure to control the light falling on film as a camera trucks in on a subject. Since with video there is no such thing as a time exposure (the video frame rate is an unvarying thirty frames per second) the optical slitscan method is impossible. But it *is* possible to squeeze and stretch a TV picture electromagnetically so that a similar result is achieved, using a Scanimate as Hays did. With the computer in the scanning mode, the portion of the image that is to appear farthest away is compressed, imparting a keystone shape to the raster. To give the effect of motion, the image is rolled — like a television out of adjustment — but because of the perspective used, the out-of-sync scanning makes the image look like it's zooming through space.

By careful planning in the optical department, and keeping the number of generations down to an absolute minimum, Hays was able to achieve satisfactory image quality, using the VistaVision film format. The Hays and Froman team also did some work on *Logan's Run.* In this case, the effects were combined with live-action photography as raygun blasts, glows and levitating force-fields.

For *Star Wars*, Jay Teitzell and Dan O'Bannon used Scanimates to create the big display in the rebel war room that showed the Death Star coming around the side of the planet Tatooine. The computer operator for the job was Roy Weinstock of Image West and the animation director was Domenic Iaia. Curiously, they wanted to achieve a look which would be like how the audience would imagine a *digital* computer display to appear, but achieved by using more economical analog equipment. The effect was originally to have been used as a rear projection in the war room set, but due to a foul-up, the screen was dismantled prematurely; and so it was added later in the optical stage with the help of a Ralph McQuarrie matte painting.

The title sequence in *Telephon* was also done with a Scanimate masquerading as a digital image display device. The story involved tiny electronic spy cameras, and Phil Zimmerman at Computer Image Corporation created an effect that was supposed to show what those cameras saw. More recently, *Time After Time* featured a time machine which travels down an abstract tunnel of energy done at Image West by Russ Maehl. The light shows that Lissajous gave in the 1800s were the direct ancestors of that time tunnel effect. (The wormhole effect in *Star Trek – The Motion Picture* appeared very similar, but was done on a digital system and projected with lasers.) Last year's *Hangar 18*, about a crashed UFO, made use of a brief analog animation sequence several times, whenever the alien viewscreen was turned on or off. The viewscreen was made to come alive as if it were a 3-D TV scanning its raster to fill a cubic volume. (Author Peter Sørensen was the designer/director of this effect, which was animated at Image West by Roy Weinstock.)

Analog computers have dominated the computer animation field for the past decade because digital imaging is such a massive mathematic task that it was not until recently that the systems became fast enough to be economically practical for animation production work. Until recently, in fact, most analog-oriented people said that digital technology would never give them serious competition. But despite recent advances in digital technology, analog systems are not likely to fall into disuse. Their great flexibility and speed will keep them cost effective for a long time to come.

Digital computing got its start with mechanical computing engines built by Blaise Pascal in 1642, which culminated in the hand-cranked adding machines common in supermarkets after the second World War. By then, the first experimental electronic computers were being built, using thousands of vacuum tubes as switching elements — and an enormous amount of electric power. The first big machines, like UNIVAC, even gained a certain degree of celebrity status for a while. In the Fifties, computers arrived in the business world, quickly making themselves virtually indispensable. Soon, "do not fold, spindle or mutilate" came to symbolize the dehumanizing side of data processing; and it was not until the recent micro-electronic revolution, with its home computers and video games, that people began warming up to the fact that computers can be thoroughly likeable little critters.

As the name implies, digital computers work with numbers — specifically the binary system, consisting of only ones and zeros. (Which is logical for an electric device since one and zero are readily represented by electric current being either on or off.) But computers were soon to become much more than fast adding machines as they assumed the capability of doing very long and complicated operations based on programmed instructions, even involving learning and decision making.

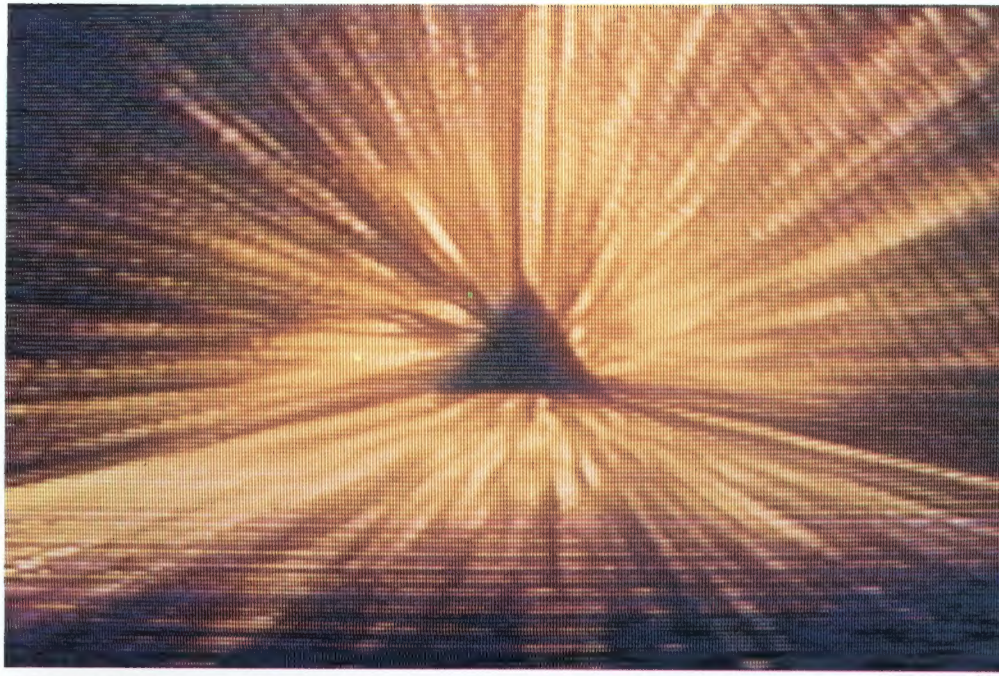
Computers vary widely in their applications, and their hardware configurations vary accordingly; but almost always they include a central processor where the main efforting takes place, a typewriter-like terminal for inputting data and commands, some kind of memory, and peripheral components that apply to the specific uses of the machine. Computer graphics setups might include such peripherals as raster or vector displays, plotters that draw with colored inks, film printers that employ electron beams, laser projectors and so forth. Inputting peripherals include X-Y coordinate digitalizing tablets for drawing, digital video scanning cameras, joysticks and other interactive devices.

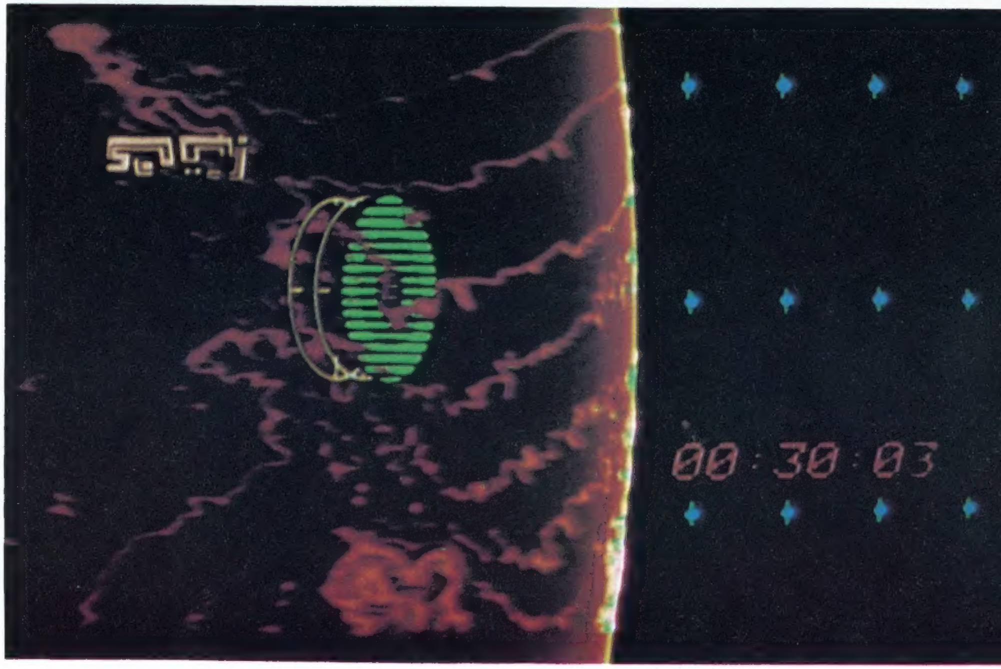
Until recently, it has been difficult for anyone without special training to use digital computers because of their complex programming. The human/machine interface has been cold and regimented — springing from the needs of the machine — and not generally attractive to artistic people. But that is currently changing, with some digital systems now even more user-friendly than analog machines. But even if digital imaging systems had *never* gotten easy to use — if they were always expensive and slow-operating — they would still be about due for their day in the sun because they alone are becoming capable of creating images with photographic realism. Given the necessary data on form, perspective, color and light, along with more subtle information like texture and reflectivity, digital computers can display an object or scene from any viewpoint, as though the object actually existed, albeit in a massless state within the machines.

When an artist wants to make a painting of something realistic, he or she knows that success is dependent on several factors to create a believable image. Perspective, form, light, color, and more must all be imitated with perfection in every detail in order to elude detection and pass for a photograph instead of a painting. As a painting gets more and more realistic, it approaches a threshold of believability, at which point the scene is taken for an actual one. The task is so difficult, however, that you could probably count on the fingers of one hand the number of one-hundred-percent eye-fooling paintings you've ever seen.

Mastering perspective is one of the most difficult tasks for a human artist; but because there is a mathematical key to it, perspective is almost a trivial matter for the computer. By precisely calculating and rendering things smaller as they get farther away, the appearance of depth is strongly suggested, which is why computer images are frequently referred to as "3-D." They are, however, only two-dimensional perspective renderings and not to be confused with true stereoscopic images — which, incidentally, can also be easily generated by the computer.

Digital picture-making systems usually employ one or the other of two rather different approaches to actually producing their images — raster displays and vector displays. The raster method works very much like an ordinary television set, sweeping out parallel lines of changing brightness, while the vector method draws in random directions using the electron beam as if it were a pencil, following the contours of the object and not wasting any time filling in space where nothing is present. "Wire cage" outline drawings are typical vector displays, while shaded, solid images are typical of raster displays. Vector systems can be made to represent solid surfaces by filling them in with lots of parallel lines — a sort of pseudo-raster — but they do not have the ability to do subtle shading and highlights. Their advantage is that they are faster than the raster hardware and their software





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PAY TO THE ORDER OF
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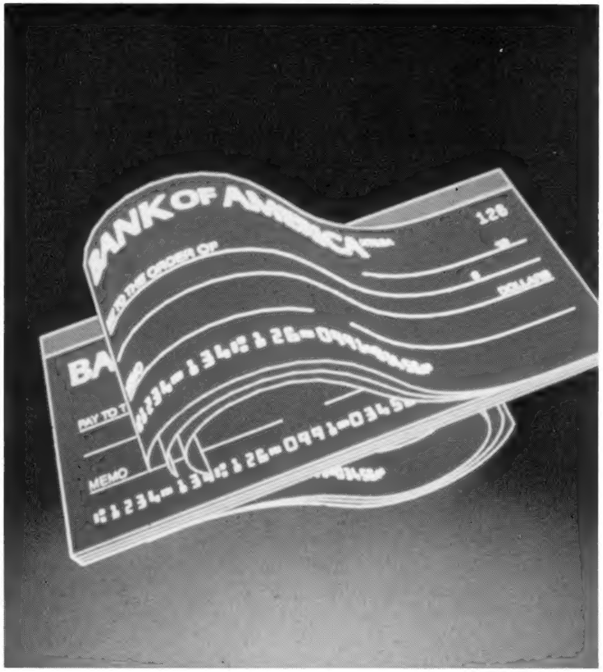

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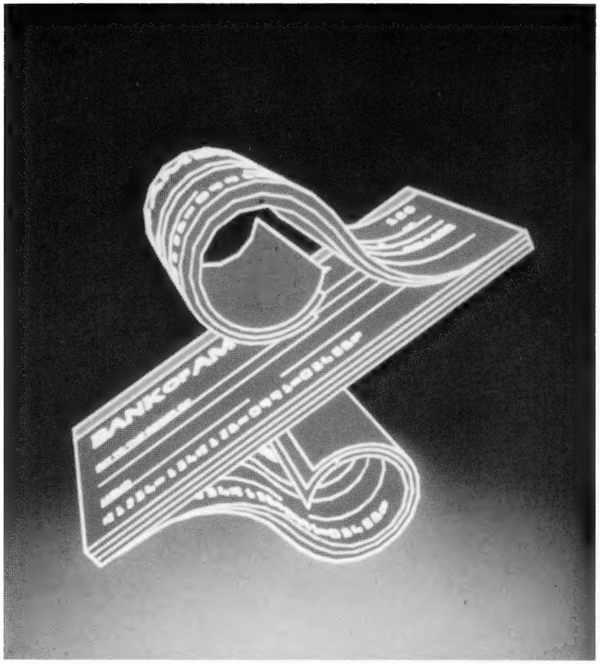
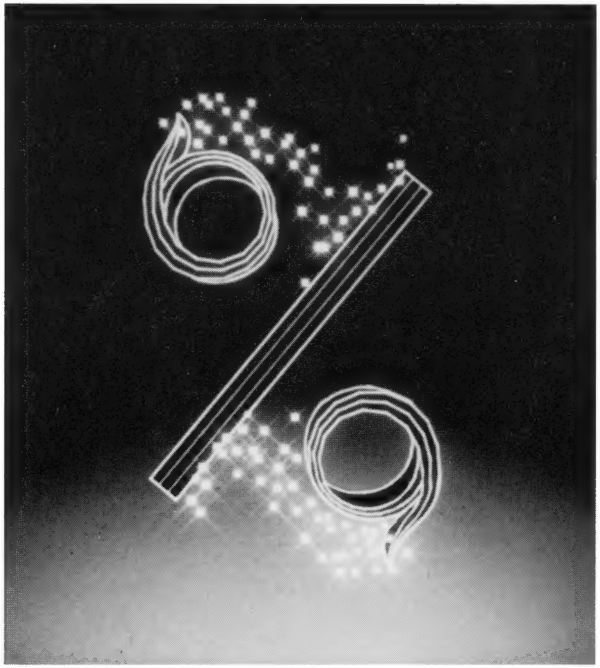




is less complex. But if the determining factor is realism in the picture, there is only one way to go — raster.

Raster display methods are most realistic because they mimic the phenomena of light as it is reflected off object surfaces, while a vector system, by comparison, makes a kind of animated blueprint. The raster system, however, is comparatively slow because it must calculate the color and intensity of each individual point (pixel) on each of the raster lines, while vector systems compute only the two end points of their calligraphic lines. Thus, a good high-resolution raster system may have to contend with four thousand lines with six thousand pixels on each line; and each pixel must be calculated for color and intensity — which is a staggering amount of work to be done for each and every frame. And all of that is *after* the machine has figured out the perspective and other physical characteristics of the object it is animating. In the end it may take as much as fifteen minutes or more to create a single frame of dimensional animation — although some kinds of animation can now be done in real-time at rates of up to fifty frames per second.

Curved surfaces are generally simplified and managed by the computer as a series of connecting flat surfaces that approximate the desired curve. By describing a curved object's surface as a large number of flat polygons, like the facets of a cut gemstone, a reasonable approximation of the object can be achieved. To smooth out the curves, the computer can perform what is essentially an averaging process between neighboring polygons. (Even many smoothly modeled images still have angular edges, since the edges have no adjacent surfaces with which to be averaged. If necessary, more work can be done to sand down those bumps.)

A problem that bedeviled software designers in the early days of digital graphics was the problem of removing hidden lines, and objects, from the scene when they were behind other things. Without a subroutine to tackle that problem, you would see all the surfaces at once — because the computer itself, in essence, "sees" the whole thing at once. Portraying the scene from a specific point of view is one of the most basic tricks the computer must perform. To find out if there are hidden lines or surfaces, it must, in effect, calculate plumb lines stretched from the objects in the scene to the viewpoint of a hypothetical camera, sort of feeling for an interruption in the paths that light rays would take on their way to the imaginary lens. If it discovers an interruption, the computer then knows it must drop lines that are in behind. But it has to think about it first. The computer must also perform a similar job in deciding when to ignore things that are out of the picture frame, otherwise the machine would be wasting its time figuring out a whole *lot* of unnecessary stuff.

In the same time frame when Harrison was developing his analog systems, pioneering digital research was being done by a team of people associated with Dr. Phillip Mittelman at the Mathematical Applications Group, Inc. (MAGI). Their objective was the development of a pragmatic way to synthesize the appearance of objects as they would look to a camera. The system

Image of a surburban airport at dusk generated on an Evans and Sutherland Novoview SP2 flight simulator. / The view from the cockpit of an Evans and Sutherland CT-5 simulator. Several trainees can "fly" together using connected simulators that allow them to practice formation maneuvers or even dogfighting. In order to prevent the rapid motion of the F-16 fighters from strobing, the system generates images at the phenomenal rate of fifty frames per second. / Vector animation done by Gehring Aviation for Bank of America demonstrates the computer's ability to twist and manipulate images. Gehring uses a pen plotter to draw the animation on paper, shoots high-contrast negatives of the drawings, and then rephotographs those negatives through color filters.

became known as Synthavision and serves as a good example of digital animation. "MAGI got started in the business of making pictures in 1967," Mittelman explained. "We had developed a series of programs for simulating the flight of nuclear radiation, and modified these programs to simulate the flight of light rays. In effect, we did a mathematical simulation of photography by tracing light rays from their source to the object being imaged, and then through a camera lens to the film plane. Using the laws of optics and reflection, we were able to make pictures with perfect perspective and shading. The key factor in our ability to picture objects was the way in which we described them to the computer. We built up every object from simple basic shapes such as spheres, boxes, ellipsoids, et cetera. These 'primitives' could be added or subtracted to finally produce the desired object. Object modeling in this manner is simple and effective. As time went on, we increased the number and complexity of the primitives until, at present, they number twenty-four. When using the Synthavision system to create movies, the art director produces the 'models' and makes pictures of them. He then uses an English-like language — the 'Director's Language' — to specify the motion of the objects, lights and camera. The computer adjusts the positions of the imaginary items on a frame-by-frame basis and calculates the picture which would be taken if all the items were real. This picture is output to a special color film recorder and is captured on 35mm or VistaVision film."

Architects are finding computer animation very handy. With it, one can stroll, as it were, up the streets towards a proposed structure, walk around it, and then go right inside and up the elevator to take a look out of the upper-story windows. For someone who is about to invest several million dollars in a building, it is reassuring to be able to visit it in such a manner before breaking ground. Cars and many other products are also being designed on computers that can give not only a view of what the product will look like, but can test the clearance of moving parts and other physical characteristics, and even generate blueprints.

Computer animation has been pioneered to a large extent by NASA and the aviation industry for the purposes of cockpit window displays in flight simulators. A great need existed for giving student pilots the experience of flying, without actually risking lives. The familiar Link trainers of World War II have evolved into some pretty impressive, multimillion-dollar hunks of hardware. Today's computerized flight simulators are mounted on hydraulic pistons that rock the cockpit for banking and turning, while the computer causes all the flight instruments to work, generates sounds and animates the view of the ground as seen from the plane. The Singer Sewing Machine Company bought the Link Company some years ago and has since been doing important research in developing real-time digital imaging systems — as have General Electric, Marconi Radar Systems, and Evans and Sutherland.

Simulators use raster displays to achieve natural lighting and color, but this is one application of raster technology where the computer cannot take all day to generate each frame of animation. For this reason, Evans and Sutherland developed the CT-5 system, which calculates images at the astonishing rate of fifty frames per second. This gives training fighter pilots a smooth effect of motion in their "dogfights."

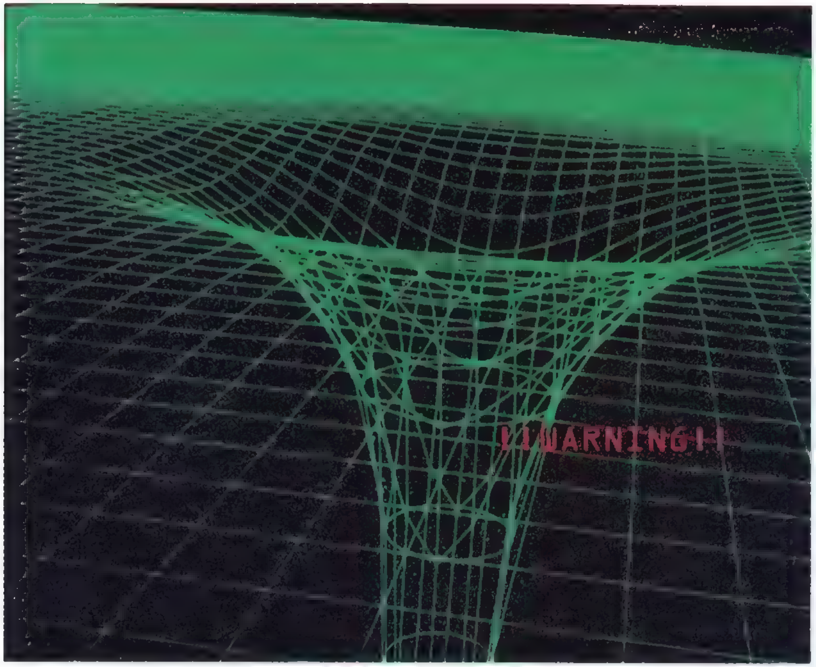
Flight simulation is done for spacecraft, too. In fact, the NASA moon walkers and shuttle pilots put in thousands of hours "flying time" before they blasted off from Cape Canaveral. But it was simulated views of the unmanned Voyager flights to Jupiter and Saturn that gave the public its best look at simulated imagery to date. Scientists working at the Jet Propulsion Labs in Pasadena wanted a way to preview what Voyager's cameras would see from various flight path options. Based upon the best available photographs taken from earth, computer animation pioneer Dr. James F. Blinn synthesized some truly beautiful motion pictures of the outer planets. In addition to these planets and their moons, the spacecraft itself was drawn into the computer and ultimately modeled from some seven hundred and fifty polygonal facets. Planetary surfaces were painted flat, directly into memory, and then by a process appropriately known as "mapping," each flat surface was wrapped into a sphere. The resulting film product was widely seen by the public on news broadcasts and on Carl Sagan's *Cosmos* program.

Blinn worked on the project with Charles Kohlhase, and together they also worked on several additional sequences for the *Cosmos* series, most notably the DNA animation, with its cloud-like molecules floating around. During the design stages of animation, they employed an Evans and Sutherland vector graphic system, which allowed them to view the choreography in real-time before committing it to film via their Automax instrumentation camera. Their central computer was a DEC PDP 11/55. Another sequence that JPL provided for *Cosmos* was an evolutionary metamorphosis that traced the major steps from primitive cell to human being. This was done with line drawings — not shaded graphics — and was digitized with the assistance of Pat Cole.

Perhaps the most luscious, totally out-of-this-world digital image synthesis being done is the jewel-like art of David Em, who works with Blinn's graphics systems on those rare occasions when Blinn himself is not. Em is an ecletic whose interests range from digital computers to theater and laser projections, and no one fails to be astounded by the surreal textural universes he creates on the computer with Blinn's modeling and painting programs. He literally paints and "sculpts" with the computer, taking advantage of the machine's ability to repeat and alter previously prepared elements. It is his fascination with texture that sets his art uniquely apart, since most image synthesis being done elsewhere is currently lacking in richness of texture.

Artists who use computers rely heavily on the data tablet, a peripheral input device which permits them to interact with their computers in much the same way as they would with a canvas. The computer works with numbers and the data tablet translates the motions of a pen-like stylus, or cursor, into information that the machine can use. It is very easy and natural to draw

The title sequence for The Black Hole *was programmed by Bill Kovacs on the Evans and Sutherland vector graphic system at Robert Abel and Associates. When plotted out in "three dimensions," the intense gravitational field of the black hole produced a funnel-like shape. The animation, directed by C.D. Taylor of Neoplastics, with technical director John Hughes, was designed to take advantage of this dramatic form. Since the computer display was in black-and-white, colors were added with filters on separate passes through the camera.*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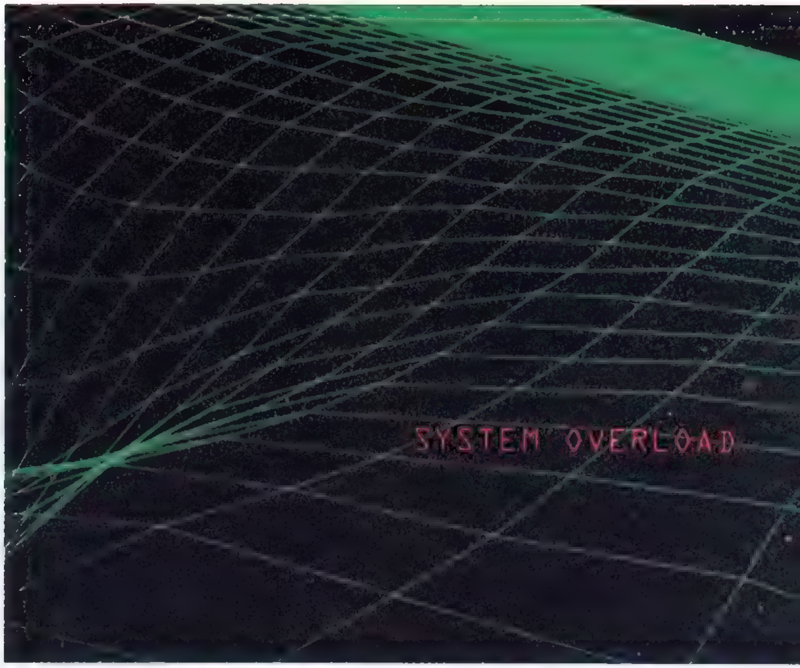
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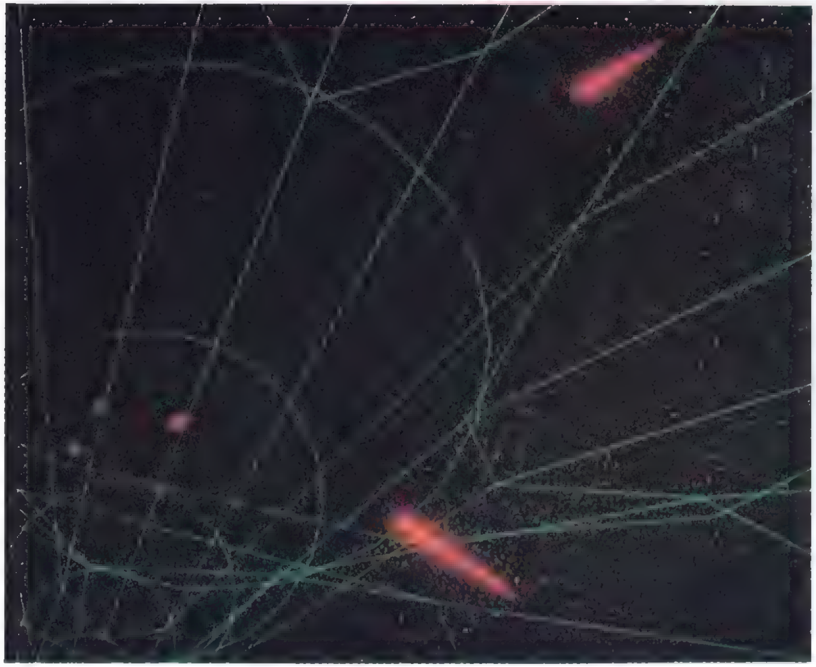
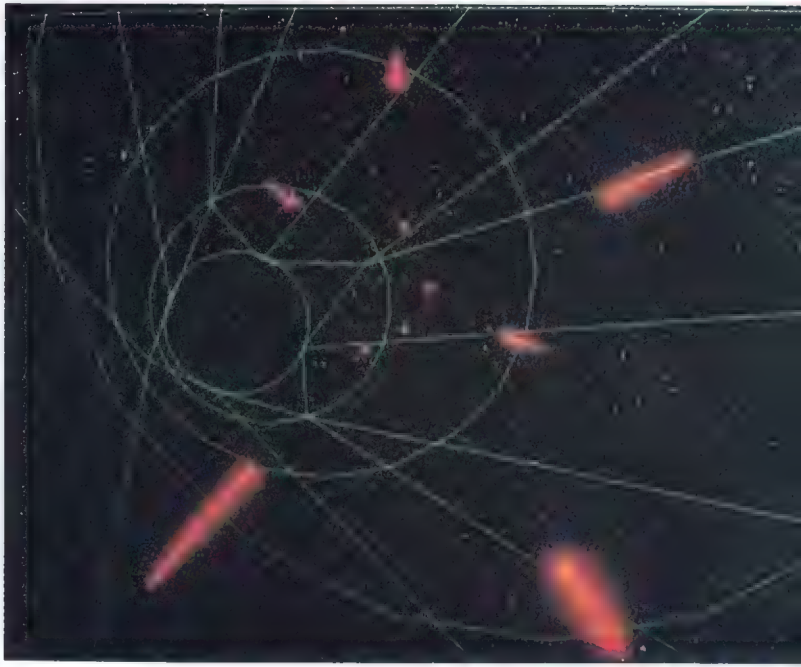
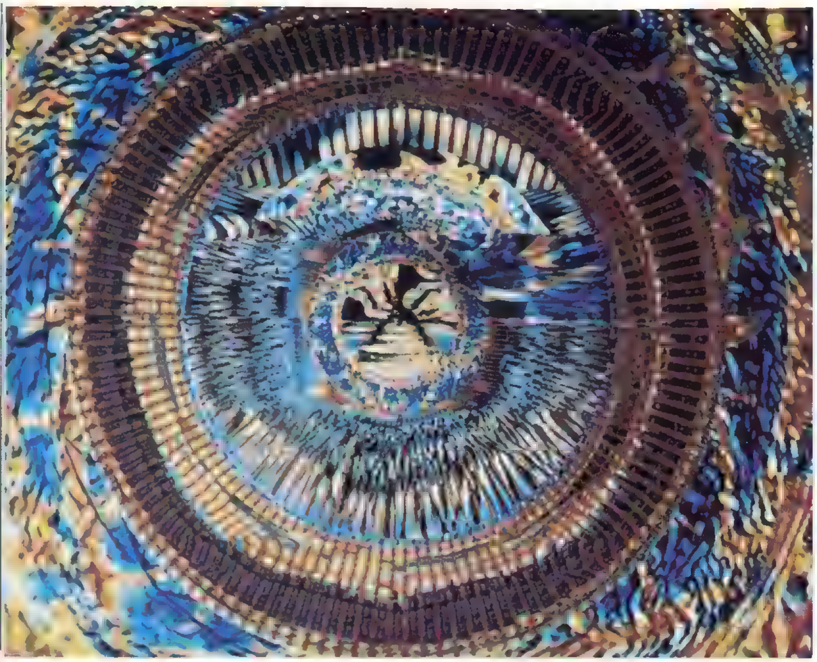
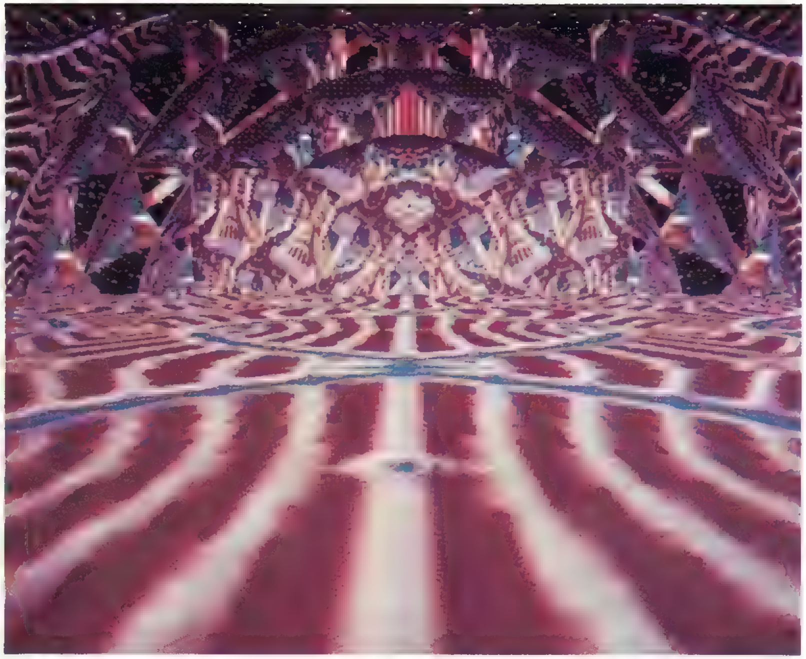
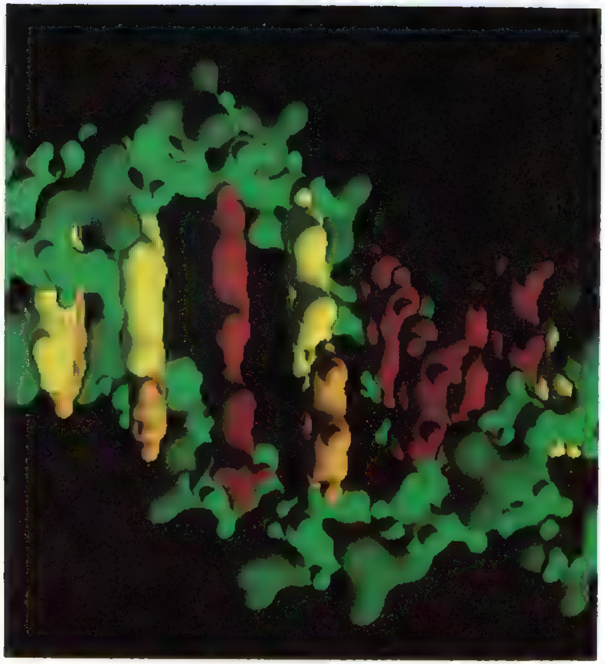










with, the only confusing thing being that the stylus makes no markings on the tablet itself; so the artist must watch the computer screen to see the results of his actions. Data tablets made by different manufacturers use different approaches to generating the electronic signals the computer needs; but the basic principle is that they have a grid of wires — like superfine graph paper — imbedded in a sheet of plastic, and the wires are sensitive to the location of the hand-held stylus. As the stylus is moved, the tablet is constantly sending updated information to the computer as to the changing X-Y position. The system was originally developed to let automotive and aircraft engineers digitalize blueprints.

In use, the artist "seeds" his stylus with a color, selects the kind of brush stroke he wants (opaque, transparent, watercolor effect, oil paint effect, airbrush, charcoal, pencil, or whatever) and proceeds to draw on the data tablet while watching his results on the monitor. But this is more than just a gimmicky way of doing what can be more easily done with paint and brushes. Digital painting is faster than traditional methods because routine operations, like coloring in and repeating elements, are done automatically; and it is impossible to ruin something by mistake, because you can always go back to an earlier stage of the artwork and start again from there. Every step of the way is retrievable from the disc memory. Furthermore, just as the stylus recalls various kinds of paint brush programs, it can also be programmed to brush in entire pre-prepared designs at a stroke. For example, it is an easy matter to paint into the humming memory of the machine a landscape covered with hundreds of trees, and then zoom into any portion of that landscape and right up to the surface of any leaf. The process is actually done in reverse. The artist first paints some different leaves on the screen. The leaves are put into the memory for recall as needed. After a tree trunk has been separately painted, the stylus can be seeded with the previously prepared leaf design, and with this "leaf brush," the tree can quickly be foliated by just tapping the stylus around on the branches. Some experimental paint sets will even distribute the leaves along the branches automatically, at randomly different distances and angles. Once a few different trees have been made, they too can be scaled down and used as "tree brushes" to populate a mountainside.

These painting systems are very "user-friendly." In other words, they have no complicated controls or confusing procedures. On the Ampex AVA, for instance, all commands are given to the machine via the bit pad. You do not even have to type to be able to talk with the machine. Instead, you just touch spots around the border of the tablet that are designed for the various commands such as "color menu," "brush menu," "store in memory," and so on.

Another device that is popular and easy to use is the joystick — a very straightforward, instinctual control that combines two or more variables into a single lever. Like on the old aeroplanes that first used them, you simply push the stick in the direction you want to go. Graphics can be moved about on the screen, or

The richly textured artwork of David Em demonstrates the wide range of possibilities for synthesized motion picture sets and digital imagery. Em uses a DEC PDP 1155 with an Evans and Sutherland Picture System II and software by Dr. James Blinn. / At the Jet Propulsion Laboratory, Blinn, in association with Charles Kohlhase, produced the computer-animated projections of Voyager's trek to Jupiter, Saturn and beyond. The sequences were widely shown on network newscasts and were featured in Carl Sagan's Cosmos *series. / Also for* Cosmos, *Blinn and Kohlhase produced a sequence on the molecular structure of DNA.*

The first digital image synthesis in a feature film was produced for Futureworld *under the direction of John Whitney Jr. and Gary Demos at Information International. Working from photographs of grid coordinates projected onto actor Peter Fonda's head, Mal McMillan and Karl Brandt encoded a three-dimensional image of Fonda into the computer, which was then able to create its own representation of him for the cloning sequence. / Computer Creations produced a curtsying Raggedy Ann as a test for the* Raggedy Ann and Andy *cartoon feature. / Cartoon animation from the New York Institute of Technology utilizing computer software by Dr. Ed Catmull. / A scene painted directly into NYIT's computers by artist Paul Xander Sr.*

spaceships flown about in "3-D" space. Similar to the joystick is the trackball, which you roll in the direction you want something to move, and the "mouse," a little gadget with wheels that you push around.

There are also touch-sensitive screens which feel X and Y movement, or the exact location of your finger. These are very effective for use by small children who simply have to point where they want the color to go. Similar, and less expensive, is the so-called light pen which can perform various functions just by being pointed at the screen. The light pen's location is sensed by means of the pixel-by-pixel scanning of the screen's cathode ray beam. Inevitably such user-friendly systems will speed the day when everyone will be "computer literate."

Perhaps the ultimate interactive system in the world today is the computer graphics lab at the New York Institute of Technology, formed under the direction of Alexander Schure. NYIT has many workstations outfitted with data tablets and joysticks, each in touch with its host computers via a kind of data shock-absorber called a frame-buffer, which cushions the flow of information to and from the central processors. The time-sharing system employed allows for several people to use the art stations at once. Like JPL, NYIT uses DEC and Evans and Sutherland equipment.

Using data tablets for art input, the people at NYIT approach the production of computerized cartoons in very much the same manner as traditional cel animators. The artist paints in key frames on the data tablet to establish the extreme limits of motion and then tells the computer how long the scene should take. From there, the machine automatically generates all the "in-betweens" that are necessary. The animator can view the action almost immediately, and anything which is deemed unsatisfactory can be changed right away. If all those frames had been painted by hand, it would be an excruciating and time-consuming process to alter the scene. With computers, however, changes can be made easily right up until the last moment.

While the animation work is in progress, it is stored on large magnetic discs until it is finally scanned onto film or recorded single-frame onto videotape. Besides the freedom to change any aspect of the animation, other advantages include being able to zoom an image up in order to paint in details, and the fact that there is no limit placed on the number of "layers" that a scene can have. (In conventional animation there are usually several layers of cels, each with separate arms, legs and so on. However, because the material they are made from is not perfectly transparent, there is a limit of about five layers which can be used at one time without affecting the background color.)

As if it were not enough to have the largest and most versatile computer cartoon animation setup in the world, NYIT is also one of the leaders in dimensional image synthesis. In fact, the folks there are currently busy making the first entirely synthesized feature-length motion picture, which has a working-title of *The Works*. It is a humorous story about a world populated by robots, with rocketships, space wars, conflict and adventure.

Dr. Lance Williams, the author and special effects director of the film at the NYIT Computer Graphics Laboratory, describes the work in process: "The computer models of the characters, vehicles, machines and buildings are defined in three dimensions. Their surfaces can be colored, patterned, and textured. They can be defined as shiny or dull, rough or smooth, or any gradation between. And they can be viewed from any angle, in any perspective, from fisheye to telephoto, illuminated by computer light sources of any color or intensity. The normal limitations of depth-of-field, intrinsic to any optical system and often important in using small models to represent large objects, do not apply to computer models. With enough computation, atmospheric effects, fog, shadows, and mirror reflections can all be simulated. Computer models are made of mathematical surfaces: spheres and ellipsoids, cylinders, cones, hyperboloids, paraboloids, polygons, and doubly-curved parametric surfaces. They are weightless and require neither wires nor pylons to flout gravity. They do not need dusting, gluing, oiling, repainting, or brushed-aluminum Haliburton luggage cases with custom foam-padded interiors. Thousands of them can be stored in a file cabinet. They enjoy, in short, most of the advantages of fantasy over reality. And the payoff, when the film comes back, are images that could not practically have been created by any other means. This is the most exciting prospect of the new digital techniques: that they are not simply a means of creating routine effects quickly and more cheaply, but that they make possible what could only be dreamed about before."

The Entertainment Technology Group at Information International, Inc. (widely known as Triple-I), is probably the most advanced producer of dimensional computer animation. (NYIT might dispute that, but Triple-I's current work with the human figure will be difficult to beat.) In the early days, under the leadership of John Whitney Jr. (son of the computer art pioneer) and Gary Demos, the Entertainment Technology Group produced the "robot vision" for the Yul Brynner gunslinger in *Westworld*, Peter Fonda's head and the samurai materialization sequence for *Futureworld*, television IDs for all three major networks, and effects footage for several commercials. (Whitney and Demos have recently departed Triple-I to form their own organization, leaving the company's current projects in the hands of effects designer Richard Taylor.)

Information International is not primarily a film production company. Their main business is making computer compositing systems and microfilm recorders for the print industry; but because they were already working with raster imaging technology, they had much of the hardware and software capabilities needed to do dimensional animation. As a result, Whitney and Demos were able to convince the company executives that synthetic image making would eventually revolutionize film making, and that Triple-I had an opportunity to get in on the ground floor.

The robot's-eye-view footage in *Westworld* was actually their first collaboration, done while Whitney and Demos were free-

lancing. What they had to do was process a series of live-action shots so that the audience would know the processed image was supposed to be what the robot was seeing. Basically, the image was sectioned into hundreds of square blocks, with all the detail in each box being replaced with a single color/shade arrived at by averaging the values of light and color that were originally in that area. The result was a mosaic that eliminated details, but retained enough information about the scene to be comprehensible. Ironically, high technology was used to produce a low technology look because, essentially, that was what people expected to see.

When *Futureworld* came along as a sequel, the Triple-I team was tasked with synthesizing Peter Fonda's head for a sequence that was to become a landmark in the growth of computer animation — a turnaround point where the fledgling technology really earned its wings in the entertainment field. The sequence involved the making of a robot clone of Fonda, and the animation was supposed to show various stages in the creation of his double's head. To achieve the effect, the Triple-I people took advantage of the computer's natural "3-D" processing steps, going from flat, faceted stages to the smoothed-out stage and finally to a lustrous, shiny surface.

The first step involved digitalizing the real Peter Fonda's face by covering him with white makeup and projecting a grid onto him. With his face thus contoured into lots of little squares, he was photographed from two angles simultaneously. The resulting pictures were then put on a data tablet and the important intersections of the grid were digitalized, giving the computer a data base from which it could model the face from any angle.

In the animated sequence, Fonda's head slowly rotates and tumbles, its surface changing at a subliminal rate from faceted to smooth. It also seems to change in substance — looking like plaster in the beginning and ending up like glassy porcelain. And while it is a truism that good special effects should be experienced but not noticed, it is unfortunate that most theatergoers never realized that what they were seeing in *Futureworld* was almost as remarkable as the fantasy it was meant to represent.

In the same film, Triple-I also introduced a sophisticated image processing technique in the so-called samurai dissolve. Unlike an ordinary dissolve, which simply tapers off one image while it brings on the next, the dissolve in this sequence involved the materializing of three samurai warriors from swarms of shimmering triangles. The triangles — originally quite large — quickly get smaller until they become like dots in a printed picture, so small as to be undetectable, materializing the samurai into solid existence. Making the men into triangles was, in a way, similar to the technique employed for the *Westworld* robot vision. Both involved a sort of pixelation process, which reduced the information on the images into geometric patterns which, in the case of the samurai, evolved into a normal-looking image. The overall sequence was achieved by shooting the set with a locked-off camera, both with and without the Japanese actors. Both shots were then fed into the computer, which could scan each frame and "recognize" the actors as being the only difference between the two shots — a trick the military does all the time with aerial reconnaissance photos. So, without the use of a bluescreen, the machine was able to isolate the swordsmen in the picture, and replace them with the triangle-patterns — in essence, doing all the required matte work electronically.

Then, around the time *The Empire Strikes Back* was starting up, Whitney and Demos came up with a plan to crack the industry's long-standing skepticism over computer simulation ever being used as a process for producing full-screen scenes with a sense of photographic reality. To demonstrate their state of the art, they proposed to George Lucas that Information International produce a test shot for him featuring a flight of X-wing fighters. Working from models provided by Lucasfilm, Triple-I first made a set of accurate blueprints, which were then digitalized and encoded in the computer — a process that took six weeks to complete. Fortunately, the fighter was a symmetrical object, so the computer was able to assist by reiterating those parts that were common in the bilateral design. A special program was even written to allow the craft's wings to scissor apart. Once the ship was encoded, the computer could duplicate any number of them; but to make each one somewhat unique, different battle scars and fuel stains were "painted" onto each. The test scene involved five of the totally synthesized X-wings, and though Triple-I and Lucasfilm were unable to come to financial terms, the viability of the technique was indeed proven to George Lucas who has since started up his own computer graphics division. The 22-person development team is headed by Dr. Ed Catmull, formerly of NYIT and the University of Utah, who years ago made history by synthesizing an articulated human hand. Fool-proof image synthesis and digital film compositing are among the group's stated objectives — as well as digital audio development and computer-controlled video editing. But don't look for synthesized X-wings in the next chapter of *Star Wars* — because rather than channeling their energies and resources into applications that would put them in direct competition with their film-oriented counterparts at ILM, the computer division is concentrating instead on developing techniques to achieve the kinds of things ILM *cannot* do, with the idea of fully integrating their unique technology into the overall Lucas filmmaking organization.

Information International is currently working with two other animation facilities, MAGI and Digital Effects, Inc., on what is by far the most extravagant film project ever attempted using digital scene simulation — Walt Disney's new science-fantasy picture, *Tron*, with Harrison Ellenshaw of Disney and Richard Taylor of Triple-I as its creative directors. Though details on the project are still under heavy wraps, the hero of the story is a computer programmer who is magically transported into a sort of parallel universe of electronic games. The electronic world will be portrayed as if made of energy and light through the use of several advanced imaging techniques including synthesized environments created by the three animation houses, and also by making use of "candy-apple-glow" motion control techniques popular in television graphics. The candy-apple process was largely developed by Triple-I's art director Richard Taylor back in the mid-Seventies when he was with Robert Abel and Associates. For *Tron*, it entailed shooting about an hour's worth of live-action on black-and-white 70mm film and then rephotographing it through colored filters to get glows and other electric-looking effects. Many of the costumes were designed by the French *Heavy Metal* artist Moebius specifically to take advantage of Taylor's painting-with-light technique.

More than twenty minutes of the film, however, will involve digitally simulated dimensional animation for the creation of fantastic vehicles and environments (many designed by Syd Mead, an old-hand stylist of the future whose work has been featured in *Star Trek – The Motion Picture* and in the forthcoming *Blade Runner*). This use of digitally generated sets is an historic milestone that future filmmakers will surely point to as the occasion when the impossible became possible — landscapes changing color and shape while gravity-free vehicles glide through the scene. Coupled with the glowing live-action and a number of more conventional effects (not to mention an adult-oriented script by director Steven Lisberger), *Tron* promises to more than make up for Disney's rather disappointing venture into *The Black Hole*.

Recently, Triple-I has also produced animation for writer-director Michael Crichton's latest picture, *Looker*. Crichton is familiar with digital methods by now, having brought *Westworld* (and by proxy, *Futureworld*) to Triple-I. For *Looker*, the principal effect needed was to make a synthesized dimensional image of actress Susan Dey — a job similar to, but more ambitious than, the Fonda head in *Futureworld*. Several other effects are also used to represent what happens when a computer is employed to analyze the human form in order to create the ideal human figure.

Perhaps the most interesting work being done at Information International, however, involves the progress being made toward animating the human figure. Prior to their work, the subtleties of human motion and form had proved elusive, almost impossible to simulate convincingly. In fact, many knowledgeable people stated flatly that it could never be done. The Triple-I team felt otherwise, however. "We thought it was absolutely necessary to do a human figure," Richard Taylor explained. "It's kind of like the ultimate in computer simulation. Otherwise, people would be bound to say: 'Obviously, you can do geometric shapes. But can you do a human being?' Well, we've *done* a human being. And he doesn't just stand there — he juggles. We call him Adam Powers, and he's incredible. He can walk in carrying his head, screw it on, become transparent, turn himself inside out, and do all kinds of things a normal person couldn't do. Plus he's standing on a geometric grid that spins around as the camera looks down on him from hundreds of feet away and then comes tumbling down and flies right through one of the objects he's juggling. Busby Berkeley would have died for a crane shot

A mechanical ant and its diminutive pilot, Ipso Facto, from The Works *— the first entirely synthesized full-length film — featuring ant design and modeling by Dick Lundin and production design by Bil Maher. The ambitious project is currently underway at NYIT's Computer Graphics Lab.*

Stylized scenes of Times Square at night were produced by Digital Effects under the direction of Jeffrey Kleiser, with software by Judson Rosebush. / Electronic compositing was introduced by Frank Van der Veer and Barry Nolan in the recent Flash Gordon. *For the few scenes employing the process, their prototype analog system effectively eliminated matte lines and other image-degrading problems associated with traditional opticals.*

like that. Adam's motion has been driven by filming a real human juggler from front view and top view simultaneously, and then tracking points of reference on his body and encoding those into the computer. So the movement is not at all mechanical, because we have basically a data base that *is* the human figure. Underlying that data base is a skeleton, if you wish — actually dots with lines drawn between them — representing different segments of the body. So we film this live-action character and rotoscope the positions — front view and top view. We encode those points to drive the skeleton, and then over that skeleton goes the fully-shaded character in tux and top hat. Then we can take that figure with that motion and place him wherever we wish.

"The data base that it takes to make a human figure is quite dense. Obviously, to do a face and hands takes a lot of data. His head, for example, and his hands were encoded from large drawings and then reduced, so they have more detail than the rest of his body. His hands have animation, and he can move his head, roll his eyes and blink — things like that. But he doesn't speak, and we aren't really changing his facial expressions right now. Those are other complex problems — ones that we know how to deal with, but right now we're just trying to show that it *is* possible to make a human figure and to make him very lifelike."

After more than three years of development, Adam Powers made his professional debut at a recent computer graphics convention. True, he still looks a bit like a plastic doll, but his motion is astonishingly lifelike, and it doesn't take a whole lot of foresight to envision his future offspring as totally believable electronic versions of the ultimate stuntman.

Other companies are also doing raster computer animation. Computer Creations in South Bend, Indiana, has a system in many ways similar to, but smaller than, NYIT's. Independently developed by former aerospace engineers Tom Klimek and Richard Brown, the system, called VideoCel, is excellent for (but not limited to) cartoon animation. Earlier this year they produced a ten-minute film for the United Nations, called *Dilemma*, that is a blend of character animation and dimensional animation. Designed by the respected London animator John Halas, the film concerns the evolution of technological achievement and how it gets subverted into destructive uses.

Still another raster-type setup, called Acmecartoon, is located in Dallas, Texas. In addition to cartoons, as its name suggests, the firm also does image processing such as computer rotoscoping, image enhancement and pixelation. The most recently formed computer animation company is Digital Effects, Inc., in New York City, one of the three outfits working on *Tron*. Digital Effects is involved solely in dimensional image synthesis and has done a number of interesting commercial spots, including a series for *Scientific American*.

In addition to the production houses already mentioned, there are many research labs and universities involved with computer animation. The University of Utah, for instance, has been the breeding ground of many computer graphics geniuses, such as Dr. James Blinn and Dr. Ed Catmull. At the University of Illinois, Dr. Tom Difanti and Dr. Dan Sandin have been exploring just about every aspect of computer animation; at the University of Ohio, Dr. Charles Csuri has developed a handy, interactive "3-D" modeling system; and at corporations such as General Electric, Singer, and Bell Laboratories, important research is also being done — often under tight security. Of these, Bell Labs is probably doing the most sophisticated work, simulating the properties of light, such as reflection and refraction, under the direction of Turner Whitted.

On the basis of the foregoing evidence, it might seem that only raster graphics is used by film and television producers. Well, almost. But there is a little company in Venice, California, called Gehring Aviation, which uses a vector graphic pen plotting system very effectively, and a big company, Robert Abel and Associates, that uses the vector graphic cathode ray equipment. Both companies do much of their work with motion control systems but each has done outstanding work with line-drawing computers.

Gehring, for example, has produced a series of ads for Bank of America which anyone with a TV must have seen by now — glowing neon-like lines that draw a bank teller tumbling in space, or a checkbook curling up into a percent sign. These were done by photographing — through colored filters onto 35mm film — animation cels drawn on paper by the computer.

At Abel's, they shoot the computer display directly from their Evans and Sutherland Picture System II with a 35mm Mitchell camera mounted in front of the screen, also using colored filters because the Evans and Sutherland high-resolution tube is black-and-white. Using this process, they too have done many extraordinary commercials — most notably their spots for Levi Strauss, TRW, Bell and a Clio award-winning ad for Cannon calculators.

Abel originally bought their Evans and Sutherland to preview motion control sequences that were to be shot using models and/or graphic art. Subsequently, they were able to make the system so accurate that it could generate mattes for their model shots. One thing led to another and soon they were doing calligraphic animation with the setup. The principal software architect and senior technical director at Robert Abel's is Bill Kovacs. Widely known in his field, Kovacs repeatedly amazes the Evans and Sutherland people by doing things with their equipment that even *they* hadn't dreamed was possible. In fact, Kovacs comes remarkably close to the solidity of raster graphics with his vector machine, building up surfaces of objects with thousands of lines (matting out the hidden lines if he wants) to form a sort of pseudo-raster. Unlike true raster, which is horizontal and does not itself move, Kovacs' pseudo-raster moves with the object and is oriented with the object being modeled.

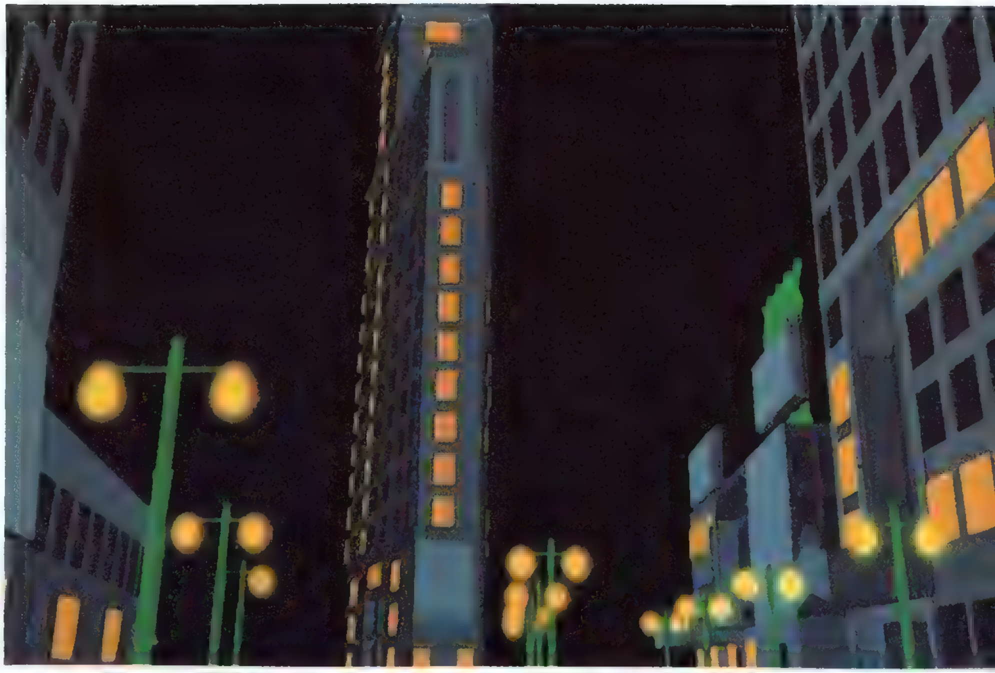
The Black Hole title sequence was done on the Evans and Sutherland by Kovacs, working in conjunction with director C.D. Taylor of Neoplastics. That animation consisted of a grid that was a gravitational field diagram, with a funnel-shaped well that represented the intense pull of the black hole. "Disney's *Black*

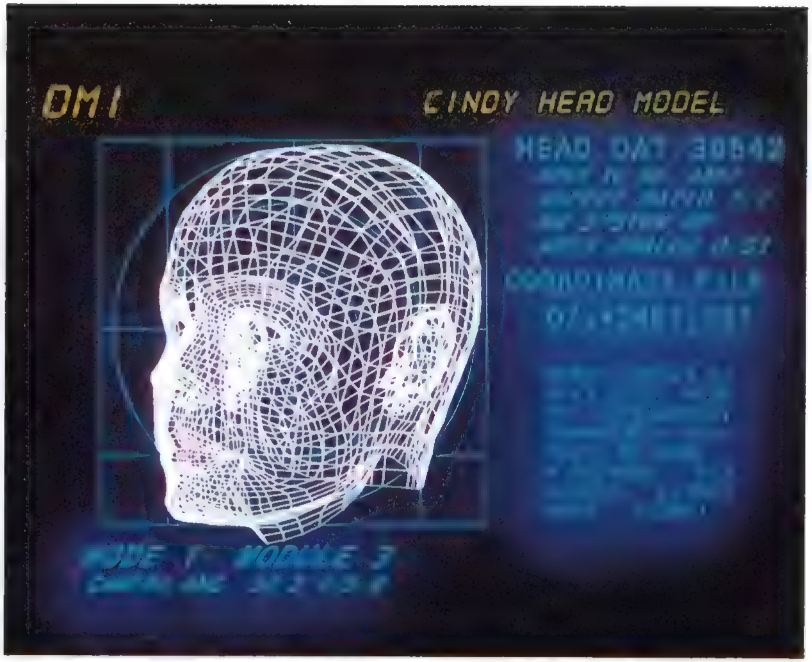
Hole storyboards were very similar to the final product," Kovacs recalled. "We took a couple of passes at it and then we generated a program for the flight path, because we needed something smooth and subtle. It was a lot of fun, because it involved some interesting moves on the black hole's gravity funnel — which was kind of curved, yet it wasn't. In a way, it was kind of like one of those old proverbs where the medieval king tells you to make something that is curved and straight at the same time. That's sort of the kind of object we were animating." The feeling of flying that the audience gets when they see the *Black Hole* animation serves to demonstrate the effective gut-feeling of depth that computer graphics can convey, even with a simple line drawing.

A similar type of animation was also employed in *Star Wars*. When R2-D2 finally arrived at the rebel base with his precious technical readouts of the Death Star, what the fighter pilots actually saw up on their viewscreen was a vector graphic animation display done by Larry Cuba at the University of Illinois. To produce his footage, Cuba used a Vector General calligraphic display with a PDP 1145 central processor. First, he digitalized photos of the styrofoam modules that Industrial Light and Magic was using to build the model trench. Then he assembled these forms on the computer, going for "the texture rather than the absolute configuration," since the final Death Star trench had not yet been built. George Lucas had specifically asked for a perspective rendering with the hidden lines *showing*, since he knew that would better represent what the audience expected computer animation to look like.

The animation came close to not getting finished on time, first because Lucas lopped three weeks off the time Cuba had to work on it, and second because of problems with the hardware. Somewhere in the bowels of his machine a tiny integrated circuit was behaving erratically and, as a result, it would not do the animation all the way through the twelve-hour shot without screwing up. Then, on the last night, when Cuba thought all was lost, he opened the window to the computer room and fell asleep on the couch. He awoke later and thought he would give it one more try. Breathlessly, he watched the computer go through the whole thing — without a hitch! Apparently the computer just wanted a whiff of the cool evening air. (Computers are notoriously fussy about temperature.)

Just as *Star Wars* had a brief sequence of digital vector-graphic animation, so did *Alien*. During the landing approach of the *Nostromo*, viewscreens on the ship showed a line-drawing display of the terrain below, with jagged mountains looming up and a small valley in the middle. That instrumentation sequence (not the one showing a patch of rectangles) was done by Alan Sutcliffe of System Simulation, Ltd., in London. Originally, it had been planned to make a model landscape out of styrofoam and digitalize it, but that proved impractical and unnecessary since there were no clear views of the territory anyhow. Instead, the mountains were produced automatically by using a random number generator to determine their height and distribution. They were, however, controlled to the extent that none would oc-

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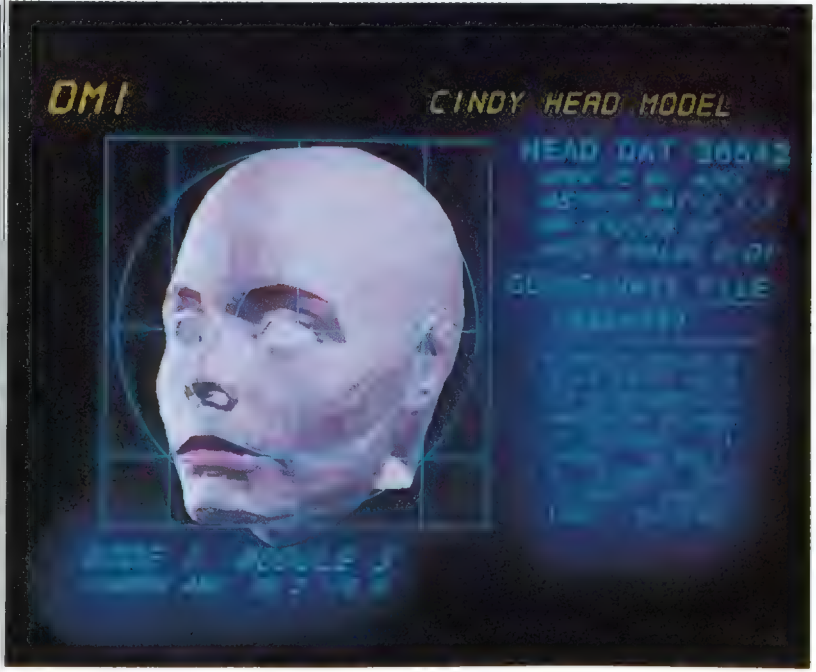
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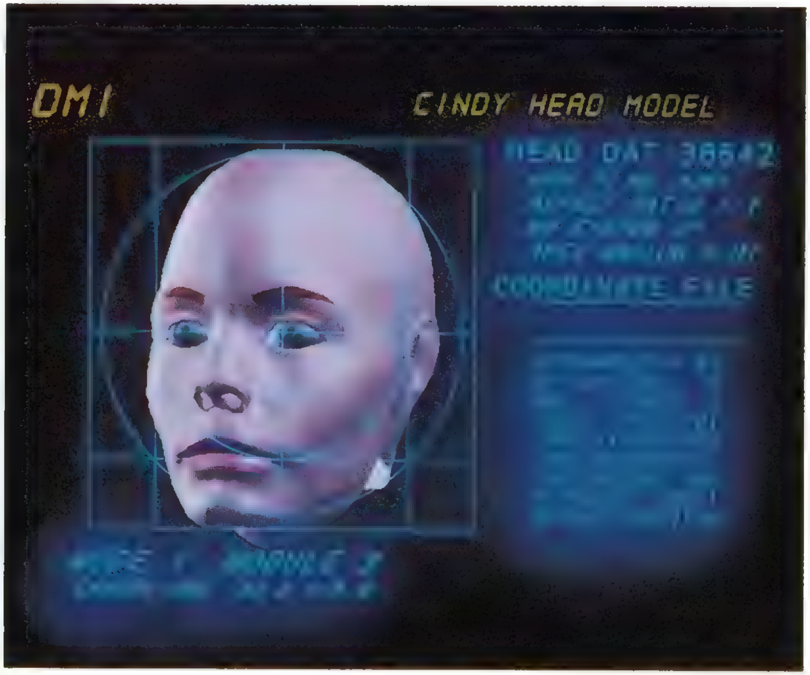
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cur in the valley landing area, and the ones in the rear would be taller on the average. The whole terrain was given a softly rolling contour by curving it slightly, based on the form of a flattened sine-wave. Minor touches included adding some ridges and a random perturbation that gave the landscape a more natural texture. All of this was laid out on a grid, using hidden line removal wherever there was overlap.

The animation shows the terrain moving up and leveling off as the landing progresses. Yet curiously, perspective wasn't necessary to achieve the effect because there were no objects — such as roads or buildings — in the scene that would have shown perspective convergence. Hence, there would have been scant advantage to calculating depth on mountains of random size during vertical descent.

Universal's Hartland facility — where the *Buck Rogers* effects were done — uses a relatively modest, but ingenious, vector graphics setup for designing scenes that would be shot using models, and to a lesser extent for generating some cockpit graphics. Colin Cantwell devised the system, which uses a small Hewlett Packard 9845-B that could "solve three-dimensional problems in terms of their two-dimensional appearance." Although it could not be used for real-time viewing — since it takes a few seconds to draw each wire-cage picture — the system did show successive stages of a move. Once the starting and finishing positions are entered into the computer via a data tablet, the system shows how the scene will progress; and on command, it will then print out on paper all the information the camera crew needs to set up the shot, as well as generate the pulses necessary to drive the motion control system. And it takes into account the spread of the lens being used, saving a lot of time and guesswork. The system was also used to produce instrument displays for the live-action fighter cockpits by shooting high-contrast stills off of the screen and sandwiching those with colored gels and glass. Normally, those types of displays would be limited to the ship designs already in the computer's memory, but on one occasion in *Buck Rogers* they had to make a display image that matched a specific shot involving ships not already digitalized. The problem was solved by rear-projecting the shot onto a transparent data tablet — in effect, rotoscoping on the digitalizing platten from the live-action shot.

"Computer languages are set up for numbers," Cantwell observed, "and not for drawing pictures. So the graphics terminal on a computer has to deal with an operating system that was originally devised without pictures much in mind. That meant that there was a lot of work for the programmer on a very detailed level. He was having to work with how bricks are going together rather than what he was going to build out of them." People like James Blinn, Bill Kovacs, Ed Catmull and the other software architects, work at this brick-by-brick level of invention, providing us with the programs that permit computers to be used as smoothly running digital paint sets and electronic modeling kits.

Traditionally, movies have always been edited by physically cutting and arranging sections of film, using a grease pencil to mark where dissolves and other optical effects are to occur. Opticals themselves involve taking different pieces of actual footage and running them through prisms and lenses onto a single piece of raw film. Such procedures have always been necessary when mating special effects with live-action.

Clearly, the fundamental minimum unit in cinema is the individual film frame — these are the "bricks" of film editing and compositing. It might seem impossible to get any more fundamental than that in image manipulation, but in video the "bricks" are the individual pixels that make up the lines that make up the picture. (Technically, the crystals of silver in a photographic image are the equivalent of pixels in the sense that they are the finest elements in the picture. But filmmakers do not have control over these individual crystals, or grains, as one does digitally with pixels.)

As discussed earlier, when an image has been converted into an electrical signal which is processed pixel by pixel, it becomes possible to perform keys, dissolves, wipes and much more — right on the spot, in real time — because nothing physical (except electrons) is being manipulated. Live television makes use of these effects every day and nobody thinks twice about the magical simplicity of the process.

Unfortunately, though, we are still saddled with that Stone Age standard of 525 lines of video resolution. Until there are four-thousand-line TV cameras, the only way to have our cake and eat it, too, is to shoot on film, scan it, store and process the image in digital form, and not go back to film until making the final print. By using digital techniques, release prints could have (as far as the human eye is concerned) the same virgin quality crispness as the original take — because for all practical purposes, digital signals do not deteriorate from generation to generation. So in practice, you could actually make hundreds of passes through an electronic "optical" printer and the quality would still be equivalent to the first generation.

Information International is working on just such a machine, which they expect to have ready in the near future. "The problem with traditional printers," explained Richard Taylor, "is that the film is more contrasty, more grainy and less color-saturated. Fringing in hair is a classic problem. They also are very time-consuming, labor intensive and non-creative to operate. Traditional opticals see the grain structure of the film and the best they can do is try to reproduce it. So, what we have done is design a system that compensates for film flaws. It is designed to know what the nature of grain structure is and elminate that, so when it scans the picture on the high-resolution screen and it's rephotographed, there is no grain build-up. The printer has greater resolution than the film has. It sub-scans the grain structure — it looks at the grain and it knows that the area should be a certain color. So when it makes the new picture it literally *knits* the image back together. With such a system, one can clean up film, enhance it, color-correct it, anamorphically compress it, stretch it, take scratches out. And it really gets to be magic when

During production on Looker, *actress Susan Dey endured a bizarre makeup session to prepare her for Information International's image synthesis team under the direction of Richard Taylor and technical directors Craig Reynolds, Mal McMillan and Mark Jaffe. Once photographed from a variety of angles, the intersecting grid marks on Dey's face and body were encoded by Art Durinski and Larry Malone, imparting a three-dimensional image of her into the computer's memory. / The image was then played out in a sequence which flows from a "wire-cage" vector diagram to a polygonal faceted representation to a smooth-shaded rendering. Lettering and incidental graphics were generated separately.*

To show the film community that digital scene simulation was a viable alternative to shooting models under motion control, John Whitney Jr. and Gary Demos of Information International digitalized a Star Wars *X-wing and produced a test scene for* The Empire Strikes Back *featuring five of the fighters performing aerobatics. Although Lucasfilm and Information International were unable to come to financial terms, the test was a success and George Lucas has since established his own computer development team.*

you start stylizing the image or combining live-action and simulation. For example, you could create a living Maxfield Parrish film by enhancing color, resolution and light."

With a few scenes in the recent *Flash Gordon* feature, electronic compositing — using analog, though, rather than digital techniques — made its debut in the movie world. Frank Van der Veer and Barry Nolan built the history-making machines that processed those scenes, after twelve years of pioneering work. Their system consists of two film scanners for the scenes to be composited, an analog mixing device similar to a video switcher, a monitor, and a film printer that has four thousand lines of resolution. As the images are combined, the results can be seen right away on the low-resolution monitor. This allows the operator to rehearse the effect until perfect, and then print it. When doing a key, the machine's sensitivity can be adjusted in color and luminence to get the cleanest possible (essentially invisible) matte edge — and it is not limited to chroma-key blue. During compositing, the system allows the operator to reposition images, and to change the hue and chroma just as easily as it's done in regular television.

Perhaps the most powerful arguments in favor of electronic compositing are economic rather than aesthetic. "One way to cut costs is to compress time," said Van der Veer. "With all the steps that you usually have to go through with opticals, to the lab and back, to the lab and back, it takes you a week to do a shot. With this system, we've cut that down to a couple of hours. You can see your end result on the monitor before you send it to the lab." Looking to the future, Van der Veer plans to build a machine that will composite as many as six scenes simultaneously, and to incorporate magnetic tape as an intermediate storage medium.

In *Altered States*, Bran Ferren used digital film scanning techniques to generate traveling mattes for use with a conventional optical printer (4:65-70). In the scenes where Edward Jessup transforms into swarms of energetic particles, Ferren used computerized edge detection methods to separate the figure from the background. First the mattes were made using both computerized and conventional rotoscoping techniques. Then the fleckles were generated; and finally the figure, background and fleckles were all combined in an optical printer.

A more ambitious project involving edge detection and separation of areas from their surroundings is the work presently being done by Ralph Weinger for Douglas Brothers Corporation in transforming old "Laurel and Hardy" films from black-and-white into color. Weinger's system first transfers the black-and-white footage to tape via high-resolution scanning. At the beginning of every scene, each object or area of color is "spotted" (indicated to the computer), and the computer then does its best to track all these areas from frame to frame. It does, however, require occasional guidance from a human "assistant" when new things appear in the scene, or in other ambiguous situations, as when something is moving so fast that its location and appearance changes radically from one frame to the next. The machine works with great subtlety, calculating gradations of shading and taking into account soft-focused edges. And according to those who have seen the results, the effect is almost totally lifelike — not cartoonish at all. In some cases, the operators were even able to improve on the existing lighting, as in one scene where the two comedians were crawling through a tunnel carrying a candle. The entire set had obviously been flood-lit with a spotlight, but in the computer-altered version, light like that from the candle flame was substituted, flickering on their faces but leaving the tunnel dark and foreboding.

The processes used in *Altered States* and the updated "Laurel and Hardy" to detect edges and isolate areas, come under the broad heading of pattern recognition. Computers are acquiring many of the skills they will be using for intelligent matting and the like tomorrow from the image processing techniques used with CAT-scans and satellite photos today. Already, it is routine for computers to look for things in pictures and isolate those things from the background. They can automatically look for the color-signature of marijuana in reconnaissance images, and point out the pot with flashing red arrows. To do this, they mull over a quantity of data and then make informed "decisions" about what is, and is not, meeting the requirements of whatever they have been told to look for. Such processes will be put to work, even at a very academic level, for detecting scratch and dust marks on film. In such an application, the computer would look for anomalies that show up only on isolated frames, as dirt marks usually do. Having detected flaws in the image, it would then automatically fill in the defect with colors gleaned from neighboring frames. At projection speed, such a "band-aid" would be invisible.

Recently, work has been done in the field of artificial intelligence in which computers have been taught to scan snapshots of ordinary objects and recognize them by inferring from the 2-D pictures what the 3-D shape of the objects must be — sort of the reverse of synthesizing an image. Then the machine compares the 3-D form that it "sees" with those stored in its memory in order to actually identify the object. If we project where this research will lead, we can see that interesting possibilities exist for super-intelligent matting. A computer could, for example, be told to remove every telephone from an entire movie, just by showing it a picture of a telephone and saying: "Go get 'em!" Then your super-intelligent image synthesizer could go in and substitute European phones (or anything else, for that matter) where each of Ma Bell's phones had been. Bill Kovacs feels this is a very exciting area: "The challenge of processing real data — be it live-action, landscapes or whatever — taking those images and manipulating them, is potentially a much more rich source of imagery than just creating objects synthetically. You could separate everything that's plaid from that which isn't plaid, look at contour, outline, shadow, compare frame to frame. You could do a lot with that, and there's a great need for it. Movie companies would come in and pay half a million bucks to save a scene, or replace somebody's head with something else, or turn a daylight scene into a night scene. That's the big apple — intelligent matting."

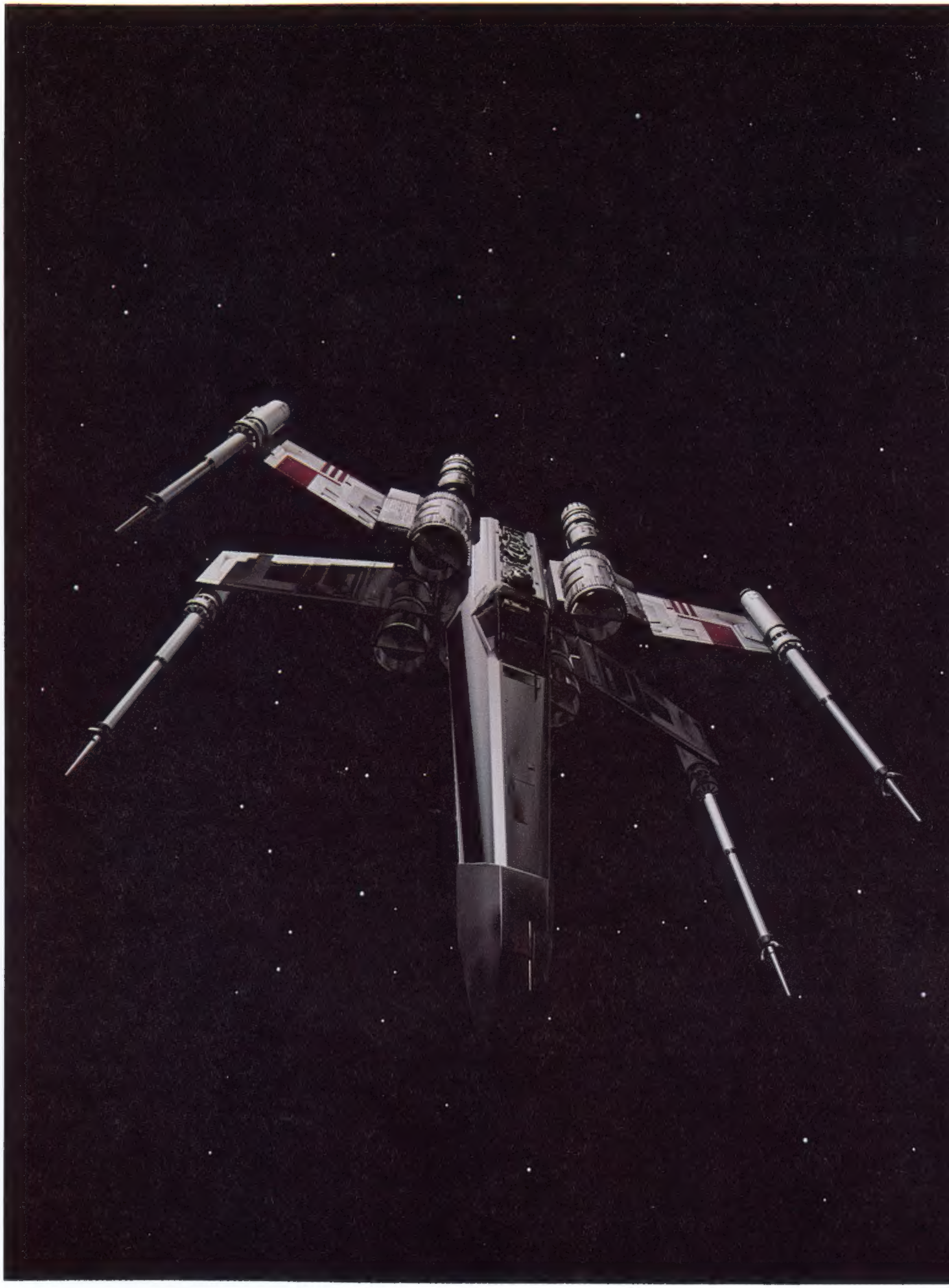
Another exciting prospect for future image conjuring is indicated by the popular digital animation trick of transforming one shape or thing into another. In Carl Sagan's *Cosmos* series, we mentioned that there was a lovely example of the effect, used to portray the flow of evolution through dozens of topological changes. Imagine a super-intelligent image processor capable of "comprehending" the 3-D topology of two scenes and told to change one into the other. The machine would probably ask a lot of questions — like "Which details in scene A turn into which details in scene B?" — but it should be possible, *someday.*

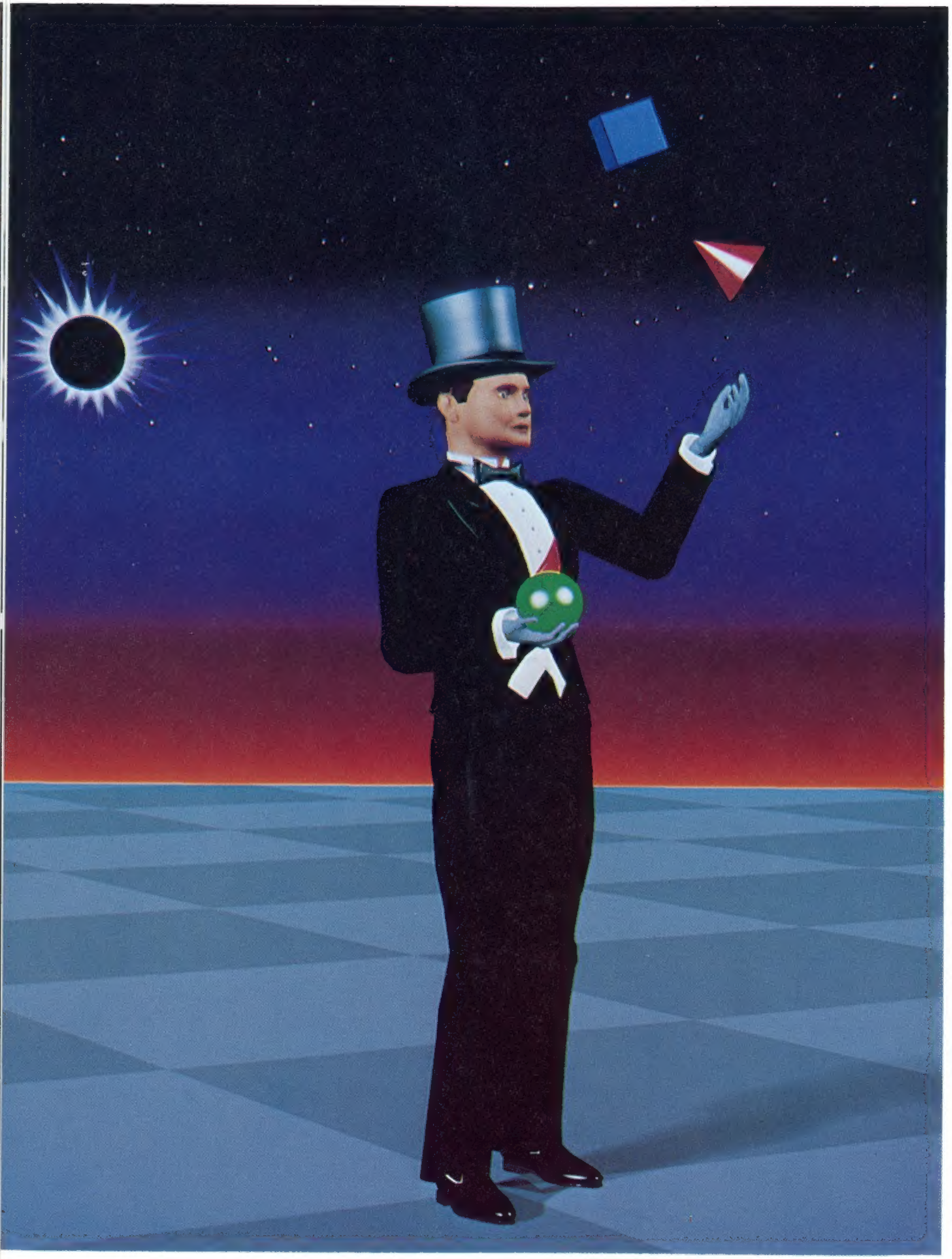
With sophisticated image conjuring techniques we will be able to do research on how the human vision system processes impressions on the retina, how it encodes them and how the two optical nerves pool their information and come up with the 3-D picture that is delivered to our consciousness. Dimensional animation and image processing will assist in such research, and will then turn right around and apply what has been discovered to entertainment technology. Research done with biofeedback techniques and computer animation could have literally mind-blowing effects for entertainment — and mind-healing benefits in psychological applications. It may turn out that there are many ways to process live-action footage so as to trigger the brain's 3-D "feelers" without having to rely upon stereoscopic photography. Using computers to doctor the focus of objects, heighten the contrast depending on how near/far they are, has already met with success in cuing 3-D perception.

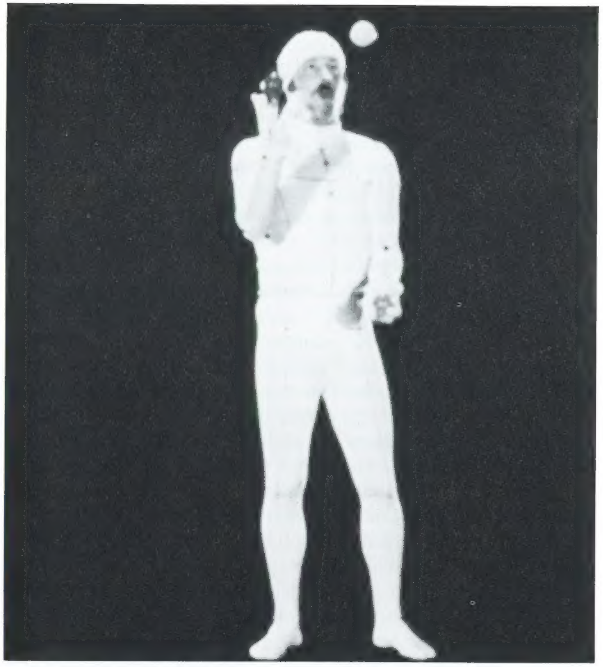
Eventually, when the technology comes down in price so consumers can afford it, there is likely to be software available that allows people to have therapeutic encounter sessions and role playing, interacting with images that are tuned to open the mind's floodgates. Perhaps "psycho-active computer animation" will come under the jurisdiction of government agencies, with only doctors being allowed to administer it. Probably not, but Daliesque movies loaded with subliminal Freudian imagery could be potent stuff.

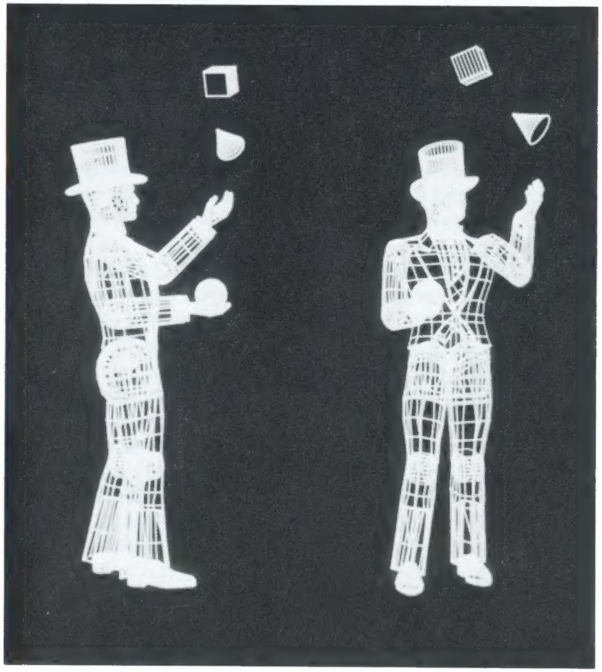
True, *some* people get a little carried away when they speculate on the future prospects for computer imaging technology. Nevertheless, one can look to the research being done by NASA, the military and elsewhere to see that it is only a matter of time before the next generations of leading-edge software will percolate down to the private sector where outrageous new synergetic applications are bound to be found.

Several years ago, a remarkable chimpanzee named Washoe was going for a walk outdoors with her (human) sign-language teacher, when suddenly an airplane buzzed overhead. Washoe, who already had a vocabulary of several hundred words and was given to inventing some new ones of her own, pointed upward with a shriek of delight and signed: "Look, a car-fly!" Other chimps have learned to communicate with humans through the use of a special computer which has big plastic word-buttons that the apes push to form sentences. Such research is leading to









important discoveries about how our own minds tick, and it is fascinating to think about what it would be like to communicate with an alien intelligence on a par with our own. Well, we may not have to wait for the flying saucers to arrive because there is mounting evidence that whales, and especially dolphins, are phenomenally intelligent, quite possibly our intellectual peers. These sea-dwelling mammals evolved into their present form long ago when our monkey ancestors were still swinging in the trees. And with their large brains, it seems probable that they developed language and oral traditions long ago. In addition to various squeaks and clicking noises, dolphins also seem to communicate using another, far more advanced method — sonar imagery. In essence, dolphins are probably living image synthesizers! The same lens-like organ with which they receive sonar images from the water is also capable (from a hardware point of view, at least) of emitting images which other dolphins could "see" in the water. Although we have not yet succeeded in building a receiver which can translate the dolphin's sonar language into pictures for our own eyes, there are people who are planning to do just that. Such research might very well focus on building an image synthesizing device that would be a sort of "3-D" sonar viewer. The translating machine should be capable of two-way communication, so it would have to be able to synthesize sonic images in the water at exactly the frequencies that the dolphins themselves use. For the human to communicate, there might be a keyboard interface similar to a Chinese typewriter, with its keys representing hundreds of basic sonar picture-words. If this scenario is someday realized as fact, we would be tuning in to a repository of ancient wisdom, alien and beautiful, which could profoundly affect our own human-centered world-view.

In the more immediate future, computer image synthesis could save the lives of countless animals that are currently being sacrificed daily in biology class vivesections. There would be little need for anyone, other than advanced medical students, to be poking around inside living cats and other creatures if there were inexpensive computer terminals, outfitted with lightpens, which could satisfactorily synthesize the action of a scalpel. In addition to the humane factor, such computers would have the advantage of being one hundred percent more convenient and sanitary. They could also be programmed to portray various pathological conditions and rare physical abnormalities that might otherwise be impossible for students to examine in detail. With stereoscopic imagery, *Gray's Anatomy* could literally come to life.

So clearly, there are many fields other than entertainment in which image synthesis can be expected to affect the world: computer games, driver education, digital art, psychotherapy — all are rapidly evolving from fiction into fact. It is no longer a question of *if* these things will become practical, but a question of *when*.

For *2001: A Space Odyssey* the model of the Jupiter-bound spaceship *Discovery* was a full fifty-five feet long. It was rather unwieldly but it had to be that big so it could be photographed with sufficient detail and depth-of-field to appear to be a quarter-mile long on screen. How many loving hours went into her construction we can only guess. Is making models on a computer any less, or more, satisfying? Obviously, it depends on the individual; and obviously a goodly number of individuals are already taking to digital imaging like flies to jam.

But while it will indeed be possible and desirable to freely *improvise* spaceships, scenery and so forth on the computers of the future, there will be a greater need for levelheaded planning and (ugh!) discipline. As the operators of the early Scanimate computers soon discovered, the near-infinite possibilities of the machine were booby-trapped blessings. It is so intoxicating just to twist the knobs and watch the pretty colors! And things happen so fast that you often make mistakes before you know it. The tendency, when faced with production deadlines, is to become stereotyped and superficial; and after a few years, a creeping cynicism seems to come over those who have been under pressure and forced to submerge their creativity for too long. The fact that one must earn a living tends to complicate the maintenance of one's personal creative integrity. But artists have always had to deal with that. Assuming one has the creative fire within, he or she must temper it with purpose and reason.

There is a mathematician named Tom Branchof who uses vector graphics to make movies about higher dimensions. He projects "shadows" of geometric figures down from as high as the fifteenth dimension (!) as moving models on his computer screen. The films are most beautiful and thought-provoking. He is an explorer who roams the theoretical stratosphere of space-time, taking his viewers through the digital looking glass and showing them the very weave of creation.

We are poised at the beginning of a new age of entertainment. Synthetic rocketships, electronic scenery, alien lifeforms, actors sheathed in electronic armor, digital prosthetic makeup , software botanical gardens, computer compositing and all the rest, will go beyond the mere imitation of the special effects of the past. With our new digital alchemy, we are breaking the laws of physics and truly pioneering new universes. Perhaps early in the next century, every home will have an image synthesizing console. The most creative artists in the medium will become international superstars, and philosophers will debate the existence of software consciousness. The pathway to such a future is already being marked.

Peter Sørensen is a Los Angeles-based computer animation consultant. He first became involved in using technological tools as art media at the Cranbrook Academy of Art in 1962. He was a designer and director of computer graphics commercials at Computer Image Corporation and Image West, and was involved with image processing on Hangar 18 *and an unused transformation test for* Altered States. *Sørensen's writings on computer imaging have appeared in* Millimeter *and* Videography.

Information International has recently broken new ground by producing Adam Powers — an animated human figure who, among other things, can juggle with all the fluidity of his real-life counterparts. Art director Richard Taylor was assisted by technical directors Craig Reynolds and Mal McMillan in producing the sequence. / Encoding the figure was a monumental tasking in itself, accomplished by Art Durinski and Larry Malone. To get the motion perfect, juggler Ken Rosenthal was filmed in a body stocking marked with critical reference points. That film was then digitalized frame-by-frame so the computer could refer to that data base to animate the Adam Powers character convincingly. / Vector renderings were used to check motion and form prior to producing the final completed figure.